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PARTIAL CONTENTS

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CONTENTS

REVIEW SECTION

IGR TRANSLITERATION OF RUSSIAN

The AGI Translation Office has adopted the essential features of Cyrillic transliteration recommended by the U. S Department of the Interior, Board on Geographical Names, Washington D. C.

Alphabet		transliteration
А	а	a
Б	б	b
В	в	v
Г	г	g
Д	д	d
Е	е	e, ye (1)
Ё	ё	ë, yë
Ж	ж	zh
З	з	z
И	и	i (2)
Й	й	y
К	к	k
Л	л	l
М	м	m
Н	н	n
О	о	o
П	п	p
Р	р	r
С	с	s
Т	т	t
У	у	u
Ф	ф	f
Х	х	kh
Ц	ц	ts
Ч	ч	ch
Ш	ш	sh
Щ	щ	shch
Ъ	ъ	" (3)
Ы	ы	y
Ь	ь	' (3)
Э	э	e
Ю	ю	yu
Я	я	ya

However, the AGI Translation Office recommends the following modifications:

1. Ye initially, after vowels, and after ъ, ь. Customary usage calls for "ie" in many names, e. g., SOVIET KIEV, DNIEPER, etc.; or "ye", e. g., BYELORUSSIA, where "e" follows consonants. "e" with dieresis in Russian should be given as "yo".
2. Omitted if preceding a "y", for example, Arkhangelsky (not "iy"; not "ii").
3. Generally omitted.

NOTE: Well-known place and personal names that have wide acceptance will be used. Some translations may include elements of previous German transliteration from the Russian; this occurs in IGR most commonly in maps and lists of references. The reader's attention is called to the following variations between German and English systems which may cause confusion when trying to check back to original Russian sources.

German	English
w	v
s	z
ch	kh
tz	ts
tsch	ch
sch	sh
schtsch	shch
ja	ya
ju	yu

TENTATIVE CONTENTS FOR THE MARCH ISSUE

TECTONIC STRUCTURE AND OIL AND GAS POTENTIAL OF THE KOLKHIDA PLAIN AND ADJACENT REGIONS[1]

by

V. B. Olenin and B. A. Sokolov[2]

• *translated by Research International Associates* •

ABSTRACT

Western Georgia is in the eastern part of the Riono-Black Sea intermontane oil and gas reservoir. Coastal Abkhaziya and the Colchis Plain is favorable for oil and gas prospecting as Mesozoic sediments are here overlain by a series of Tertiary and Quaternary rocks. From the Recent tectonic pattern, evolution, age, and composition of the present complexes the authors could outline three tectonic regions: Guri, Colchis and Abkhazsko-Megrel.

The geological pattern of the Colchis region has recently become better known. Borehole data indicate the presence of a heavy Cretaceous carbonate series (over 1, 000 m thick) overlain with sharp angular unconformity by Pliocene and Quaternary argillo-arenaceous sediments.

From data obtained by seismic prospecting, drill-hole exploration and geological survey the conclusion that all brachyanticlines in the Colchis region might be grouped into three anticlinal zones, namely northern-Colchis, central Colchis and southern Colchis. Within the northern Colchis zone three brachyanticlines (Ingur, Ochemchiri and Kodor) are distinguished. The same confinement of separate uplifts to the anticlinal zones may be observed in the Abkhazsko-Megrel and Guri regions, where an overall complex of Tertiary sediments is developed. In the area under discussion two structural layers are isolated: the lower Domeotic and the upper, consisting of Pliocene-Quaternary rocks. The lower layer is characterized by intermittent folding, the upper one -- by nearly horizontal bedding. The oil content of the Cretaceous sediments in Western Georgia is known from drilling data and abundant oil and gas occurrences. In this connection certain Colchis brachyanticlines are of great interest for oil and gas prospecting within the Cretaceous carbonate complex.

* * *

The Riono-Black Sea oil- and gas-bearing basin is one of the largest basins in the U. S. S. R. The basin is bordered on the north by the Crimean and Caucasus mountains, on the south by the Ponta mountains, and on the east by the Dzirulsky crystalline massif. The western border of the basin, according to I. O. Brod [1], is tentatively considered to be an underwater platform separating the Black Sea depression into two parts and extending from Sevastopol to Sinopa (fig. 1).

The axial part of the basin is covered by the Black Sea and is, therefore, inaccessible for direct investigation. The coasts of the southern Crimea and the northwestern Caucasus are composed of Mesozoic and Paleogene [equals Paleocene through Oligocene] rocks which truncate a system of folds constituting part of the Alpine structures of the Crimea and Greater Caucasus.

Southeast of Gagra, deformed Cretaceous and Jurassic beds are separated from the continental shelf of the Black Sea depression by a shelf zone and a coastal-plain belt where Mesozoic rocks are covered by a succession of Tertiary and Quaternary rocks. This coastal plain belt continues through coastal Abkhaziya and widens considerably at the eastern end of the Black Sea. This extensive plain is of great interest for oil and gas prospecting; it has been the site of continuous downwarping and sedimentation over a long period of geologic time. Oil and gas could have accumulated in the Mesozoic and Tertiary rocks under the cover of younger sediments.

The history of the development and structure of the northern and eastern margins of the Riono-Black Sea basin have been studied by E. K. Bakhaniya [3], P. D. Gamkrelidze [5], A. I. Dzhanelidze [7], A. G. Laliyev [10], B. F. Meffert [12], V. P. Rengarten [14], M. M. Rubinshteyn [16], A. V. Ulyanov [17], V. E. Khain [18], and others.

Rengarten distinguished three tectonic zones in the eastern part of the basin: 1) in the north, the Greater Causasus fold zone, whose southern boundary trends toward the sub-Caucasian zone north of Sochi: 2) in the central part, the trans-Caucasus weakly folded zone, which has been divided into the Abkhazsko-Rachin and Rionsko-Dzirul subzones; and 3) in the south, the Adzharo-Trialet fold zone.

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[1]Translated from Tektonicheskoye stroyeniye i perspektivy neftegazonosnosti Kolkhidskoy nizmennosti i smezhnykh rayonov: Sovetskaya Geologiya, 1959, no. 5, p. 96-108.

[2]M. V. Lomonosov Moscow State University.

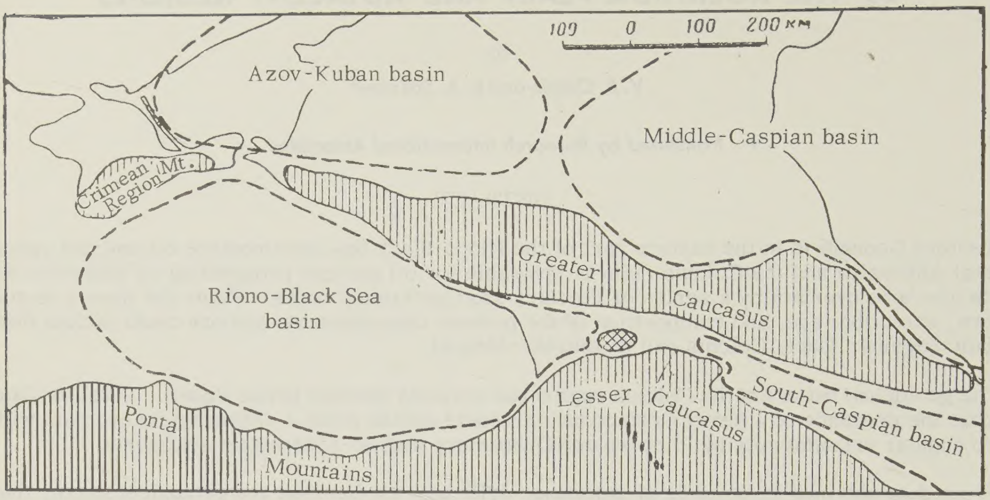

FIGURE 1. Scheme for the location of the Riono-Black Sea oil and gas basin

mountainous folded structures

Dzirulsky crystalline massif

margins of oil and gas basin

Dzhanelidze [7] includes the Abkhazsko-Rachin and Rionsko-Dzhirul zones of Rengarten in a single zone which he calls the Gruzin (Georgian) block. The Abkhazsko-Rachin subzone, whose southern border passes approximately from Sukhumi to Kutaisi, according to the classification of Dzhanelidze, is a transitional zone between the Greater Caucasus fold zone and the Georgian block. The western part of the Georgian block, within which the Colchis plain is situated, is considered a separate tectonic subzone by Dzhanelidze.

The territory under consideration in this article is situated in the western Abkhazsko-Rachin zone and the Georgian block.

On the basis of its present structure, tectonic development, and stratigraphy, this area can be divided into three tectonic regions: The Guri, the Colchis, and the Abkhazsko-Megrel, with the exception of the western part which is located in the Abkhazsko-Rachin transitional subzone.

As a result of an analysis of the structure of the Georgian block in the region of the Dzirulsky crystalline massif and adjoining areas, Dzhanelidze has described apparent surface folding typical of areas having a relatively shallow basement. According to Dzhanelidze, a sedimentary mantle with surface folds and a shallow crystalline basement define the term "block" [7]. Surface folding is similar to intermittent folding of the geosynclinal type (according to Khain's classification [18]). Gamkrelidze [5] and Meffert [12] have determined that the linear, geosynclinal folding of the Greater Caucasus and Adzharo-Trialet are replaced by intermittent folds toward Colchis. The folds, as can be expected, are overturned in the direction of Colchis.

The structure of the Colchis region has not been understood until recently. During the past 8 years or so, seismic studies and deep drilling have been conducted in the Khobi and Rioni interfluve (D. A. Buleyshvili [2]). As a result it is known that in the Colchis area there is a series of Cretaceous carbonates as much as 1,000 m in thickness (no older rocks have been found) and overlain, locally, by thin Paleocene and Eocene marls and limestones. The Cretaceous rocks constitute an underlying and different structural layer, typically forming distinct, but rather gentle, uplifts separated by wide depressions. Oligocene and middle and lower Miocene rocks are absent; the lower structural layer is overlain with sharp angular unconformity by conglomerates, sandstones, and clays of the Maotis [upper Miocene?], Pontian, and younger rocks of Pliocene and Quaternary age. These are as thick as 2,000 m. Rocks of this succession typically form gentle monoclines (the upper structural layer). [Figure 2 is a schematic structure map of the area].

By correlation of seismic, drill, and geologic data on the Colchis region, a series of new structural elements have been revealed. Schematic structural maps (figs. 3 and 4) and cross sections (fig. 5) contoured on the surface of the Upper Cretaceous have been constructed.

There are three known uplifts in the Colchis region: the northern Colchis, the central Colchis, and the Pechor (southern Colchis) anti-

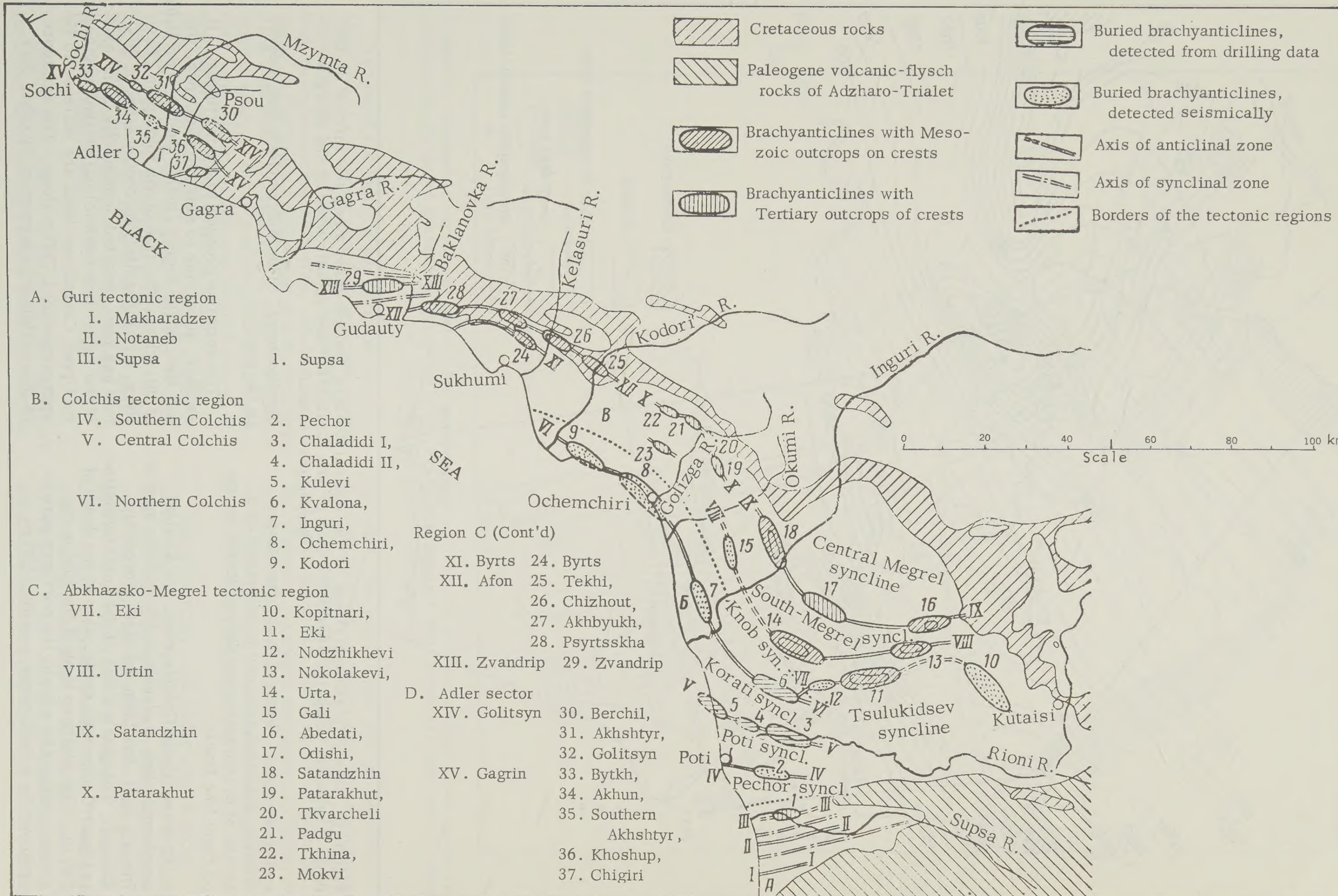

FIGURE 2. Tectonic structure of the Colchis lowland and adjacent regions

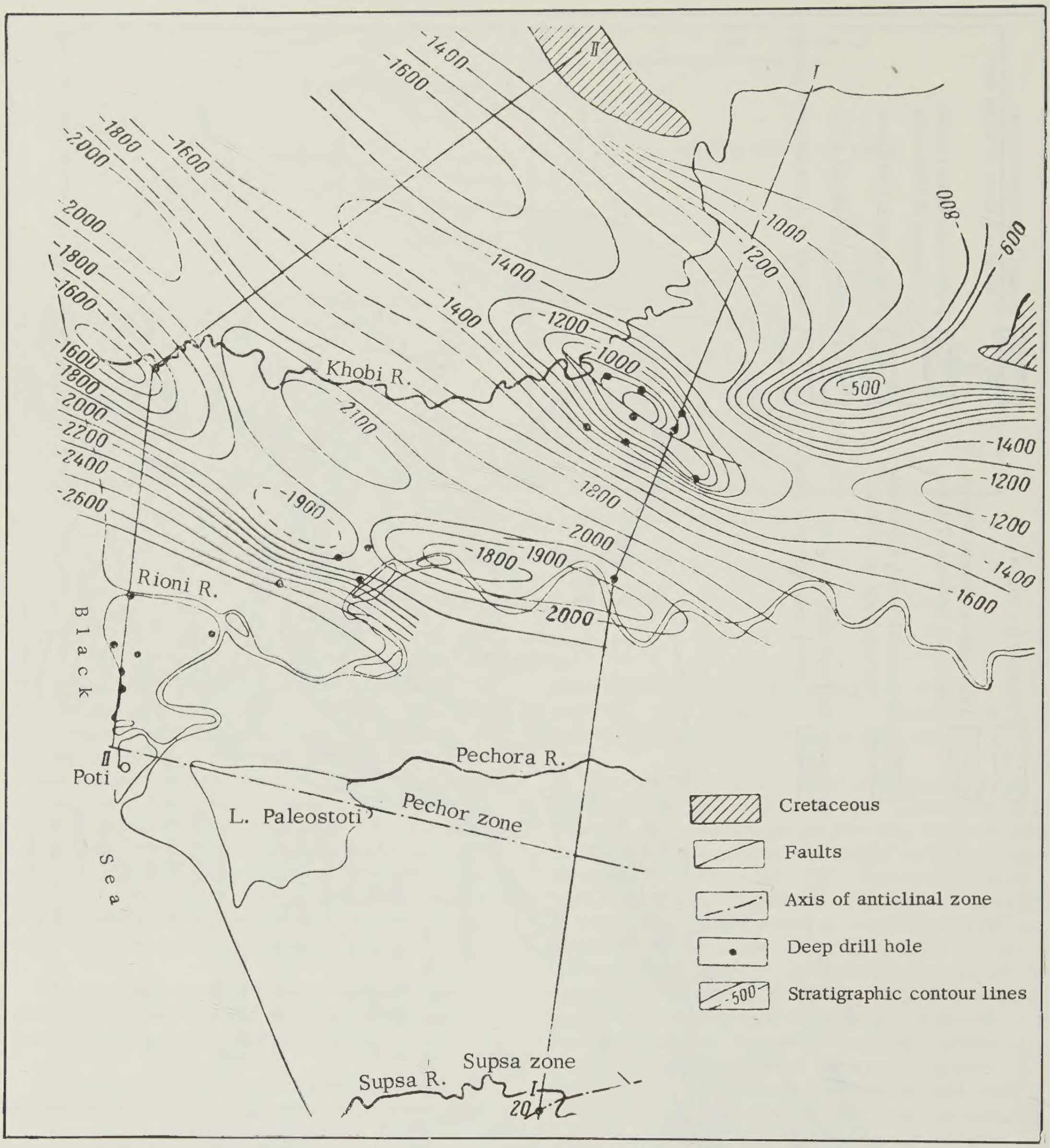

FIGURE 3. Schematic structural map of the central Colchis lowland drawn along the surface of the Upper Cretaceous (compiled from drill data of NPU "Gruznefti" and seismic work of the Georgian geophysical bureau)

anticlinal zones Each of these extends for considerable distances and is composed of a series of brachyanticlines having domes strung on them like beads.

In the northern Colchis zone, the Kvaloni brachyanticline, a sizable uplift striking approximately east, has been the most thoroughly studied. The gentle crest of the brachyanticline in Upper Cretaceous rocks, lies at the depth of 700 m. The southern limb of the fold is the steeper and cut by a fault; the northern part is upthrown by a fault of not less than 100 m displacement. The fault surface dips steeply to the north.

The anticline plunges to the northwest. It saddles, according to seismic data, near the left bank of the Inguri river. On the right bank of this river, the axis of the fold again rises. Here, a brachyanticlinal continuation of this fold has been detected seismically. The axis of the Inguri brachyanticlinal strikes southeast. Its Upper Cretaceous beds are believed to lie approximately 1,700 m deep. The existence of this anticline is supported by other data.

FIGURE 4. Schematic structural map of the northwestern part of the Colchis lowland drawn along the surface of the Upper Cretaceous (compiled from drill-hole data of NPU "Gruznefti" and seismic work of the Georgian geophysical bureau)

Studies of the Inguri river terraces in Megreliya have shown that they are most widely developed on the left bank of the river where they cover a considerable area. On the right bank, the terraces are few and poorly developed. This indicates that the river at one time flowed farther east, at the foot of the Urta mountains; with time, the river bed was shifted westward and began undercutting the Satandzhin ridge. Several other rivers on the southern slope of the Caucasus (Bzyb, Belaya, Gumista, Kodori, and others) have undergone progressive displacement either to the west or east in their lower courses; this is due to contemporary tectonic movements.

Except for a sector in its lower course where the river turns sharply to the south and then to the west, the Inguri river bed has been displaced along all its length after emerging from the Cretaceous gorge. The width of the river bed, consisting of a whole series of branches and channels, attains a maximum of 700 m; at the bend, it narrows to 50 m. The obstacle which prevents the river from altering its course is the rising Inguri uplift.

The Ochemchiri and Kodar uplifts occur farther to the northwest in the northern Colchis zone. They both strike approximately southeast. The northern limbs of the folds dip gently; the structure of the southern limbs is almost completely unknown. Upper Cretaceous sediments are situated at an approximate depth of 1,600 m. The existence of these brachyanticlines has been postulated on the few seismic

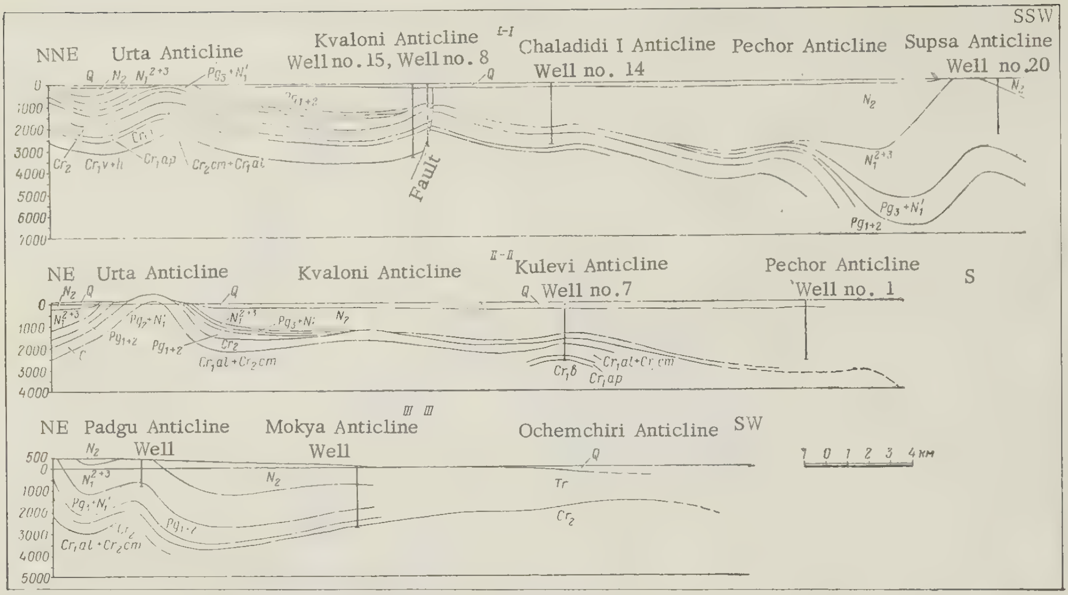

FIGURE 5. Schematic geologic sections through the Colchis lowland (compiled from drill-hole data of NPU "Gruznefti" and seismic work of the Georgian geophysical bureau, with the use of data collected by E. K. Bakhaniya and A. G. Laliyev)

profiles taken in this area. Almost all of these indicate a rise in a southwest direction in the reflecting horizons. Such an uplift cannot continue for any great distance when the regional dip of the strata is toward the Black Sea. Consequently, an anticlinal crest should exist at some distance from the shore and within one of the sectors of the Black Sea coastal shelf.

East of the Kvaloni anticline, the axis is apparently divided. One prong extends to the south-southwest; it is weakly recorded on the seismic profiles. The second prong can be traced from the Kvaloni anticline to the northeast; it includes the Nodzhikhevi, Eki, and Kopitnari. This prong may be considered an independent anticlinal zone located within the adjacent Abkhazsko-Megrel region.

The northern Colchis anticlinal zone is terminated on the north and south by depressions. The Khobi syncline, which reaches its maximum depth in the Inguri river region, can be clearly seen north of the Kvaloni anticline. South of the northern Colchis anticlinal zone is the central Colchis anticlinal zone which includes the Chaladidi I, Chaladidi II, and Kulevi uplifts. The Chaladidi I anticline is a very gently dipping brachyanticline striking almost east. Cretaceous rocks within this fold lie at a depth of 1,800 m. This brachyanticline is linked on the northwest to the Chaladidi II uplift, by a small saddle.

The Kulevi uplift has not been sufficiently studied. It is quite possible that part of it extends under the Black Sea. The depth of the Upper Cretaceous beds in its crest is 1,500 m, according to drilling data.

The central and northern Colchis anticlinal zones are separated by the shallow Korati syncline, which has a maximum depth of 2,100 m to Cretaceous rocks. The deeper Polyskaya syncline borders the central Colchis anticlinal zone on the south. South of Poti, Laliyev, on the basis of geophysical data, has described another uplift, apparently situated in an anticlinal zone striking east which we have called the Pechor or southern Colchis zone. As yet, its structure has not been fully explained. Like the preceding zones, it is composed of Cretaceous and slightly dislocated Pliocene rocks. The Pechor anticline is separated from the Guri Pechor uplift by a syncline, in which Cretaceous rocks are situated at great depths. This syncline, apparently, is filled with great thicknesses of Paleogene and Neogene [equals Miocene through Recent] rocks; the complete section is exposed farther south. The absence of Paleogene and Miocene rocks in the Colchis region is due to pinching out and faulting on the northern limb of the Pechor syncline.

The Guri tectonic region, adjacent to the Colchis region and sometimes called a depression, is at the western margin of the Guri-Kavtiskhev subzone, which has been identified by Gamkrelidze [4]. As a result of the pre-Oligocene and pre-mid-Miocene intensive folding, this tectonic region was incorporated in the Georgian block. It forms, in its southern part, a transitional zone with the Adzharo-Trialet geosyncline, of which this region had

formerly been a part.

The oldest rocks in the Guri tectonic region are Upper Cretaceous limestones which outcrop at the crests of some uplifts. Overlying them are strongly deformed Paleocene to middle Eocene flysch formations, several thousand meters thick. Equally thick Oligocene and Neogene arenaceous-lutaceous rocks lie above them in sharp angular unconformity. The Oligocene and Neogene rocks are folded in gentle brachyanticlinal structures separated by wide synclines.

As can be expected, the folds have more gently sloping southern limbs which are complicated by south-dipping thrusts. The individual brachyanticlines are grouped into several distinct anticlinal axes. These axes, unlike the axes of analogous structures in the Colchis region, are parallel to the basic strike of the folds in the Adzharo-Trialet system, thus indicating their genetic relationship with the latter.

The Guri region, generally speaking, is a large synclinorium; the Guri syncline is situated in its center. To the north, the Supsa and Notaneb anticlinal axes can be identified; they are separated by the Dzimit syncline. The Makharadzev anticline and syncline lie to the south. The suncline is adjacent to the Adzharo-Trialet fold region; although separated from it by a major regional thrust. The northernmost Supsa zone demands particular attention from the above-mentioned anticlinal zone of the Guri anticlinal region. The Supsa-Ompareti uplift occurs within this zone; it contains the only known oil pool in the Riona-Black Sea basin. Here, several arched-layer pools have been found. Sandstones of middle Sarmatian age are the producing formations.

The Abkhazsko-Megrel tectonic region occupies, for the most part, the northwest Georgian block. The rocks of this area form two distinct structural layers. The lower stage consists of carbonate rock of Cretaceous age and terrigenous sediments of Paleocene and Miocene ages; their thickness exceeds 1, 000 m. This series is warped into gentle folds of the intermittent type, inclined, as may be expected, toward the south. It is covered by the angularly unconformable Maotis and younger formations, several hundred meters thick. Pliocene and Quaternary sediments form the upper structural layer; these are characterized by gentle dips.

The extreme eastern and western sections of this tectonic region differ somewhat in their structures. These are known in the literature as the Megrel and Gudauty depressions.

In the Abkhazsko-Megrel region, a whole series of anticlinal axes can be distinguished. In eastern Abkhaziya, the Patarakhut anticlinal axis has been known for some time; it stretches from southeast to northwest and includes several separate uplifts (Tkhina, Padgu, Tkvarcheli, and Urta). Maikop and Sarmatian rocks outcrop in the centers of these uplifts. Several anticlinal axes can be easily traced along the Cretaceous beds north of Sukhumi.

The Byrts anticlinal zone, well developed in relief, has a sub-Caucasian strike in its eastern part; in the Novyy Afon region, it changes to the west and then plunges toward the sea. Upper Cretaceous limestones outcrop on the highest domes. The Afon anticlinal axis passes to the north of the Byrts; it includes the Tekhi, Akbyukh, Chizhout, and Psyrtsskha brachyanticlines which contain Jurassic and Cretaceous rocks in their centers. This axis, defined by Paleogene rocks, plunges under the sea south of Gudauty; in the east, it apparently passes under Maotis formations. There is reason to suppose that the Afon and Byrts zones, plunging under Tertiary rocks in the east, do not fade out, but continue and join with similar axes of eastern Abkhaziya and Megreliya. Here, they appear in the form of very gradual uplifts of the Mokva brachyanticline type and of the Patarakhut zone.

In Megreli, a whole series of major brachyanticlines can be identified. At their crests, rocks of Cretaceous age occur (Abedati, Nokolakevi, Eki, Urta, Satandzhin brachyanticlines). Meffert [11] has suggested that these uplifts comprise two anticlinal belts. One extends from Lechkhuma through Abedati, Nokolakevi, and Urta, then turns sharply to the north. It can be traced as the Satandzhin anticline which forms an arc dividing the Megrel depression into two unequal parts. Meffert [12]has also distinquished another belt south of this arc which passes through Eki uplift. His views are supported by S. I. Ilin and A. G. Eberzin [9], as well as by E.K. Bakhaniya [3], who claimed that the the Satandzhin anticline was a continuation of the Urta fold. According to M. F. Dzvelaya [8], there is no basis for correlating the Urta anticline with the Satandzhin. Both these uplifts are divided by a wide syncline. The eastern continuation of Satandzhin can be traced along Tertiary rocks somewhat south of Zugdidi.

Dzhanelidze [6] and a good many other investigators consider the individual brachyanticlinal uplifts of the Megrel region within a single anticlinal belt as having a linked distribution. In our opinion, in view of the tectonic structure of the regions adjacent to Megrel, the problem of the structure of this region should be approached in a somewhat different way.

We call attention to several important factors: the axial orientation of the above-mentioned brachyanticlines, which, in general, form a system of parallel folds bending toward the south. The uplifts which are primarily composed of Cretaceous rocks along extensions of

the anticlinal axes are, in certain uplifts, composed of Tertiary rocks as well (Odishi and others). On the basis of this, we may assume several anticlinal axes are present within the above-mentioned uplifts. In general, three anticlinal axes can be distinguished: the Satandzhin, including the Abedati, Odishi, and Satandzhin uplifts; the Urtin, composed of the Nokolakevi and Urta brachyanticlines; and, in its western extension, the Gali uplift. The existence of the Gali has been postulated on the basis of fregmentary seismic data. At the brachyanticlinal crest the depth to the Cretaceous rocks is approximately 1, 700 m. These zones divide the Megrel depression into several parts. North of the Satandzhin zone is the central Megrel or Doberazen syncline, whose limbs are contorted into second-order folds. The southern Megrel syncline is situared between the Urtin and Satandzhin axes.

The Eski is the third axis. The Nodzhikhevi uplift is located at the extreme western end of this axis. Here the Upper Cretaceous crest is situated at a depth of 500 m. The crest has a slight plunge; the limbs have steeper dips. Quite possibly, this uplift is a secondary deformation on the western periclinal termination of the major trunk of the Eki brachyanticline, which is clearly reflected in surface relief. Turonian limestones outcrop on its crest. The southern limb is cut by a fault which, according to Bakhaniya, is a continuation of an similar fault which cuts the southern limb of the Kvaloni anticline.

It is interesting to compare these data with the conclusions of Rubinshteyn [15] on the coincidence of earthquake epicenters in western Georgia with a line passing along the margins of anticlinal uplifts of southern Megreliya (in the vicinity of the Kvaloni-Eki fault). It is possible that these disruptions are caused by a deep-seated east-trending fault in the upper layers of the earth's crust which divides the Georgian block into separate smaller blocks. The approximate depth of the fault, judging from the distribution of earthquake epicenters, is 15 kilometers.

To the east, the crest of the axis undulates. It forms the large Kopitnari fold, detected seismically (G. M. Prangishvili [13]). It strikes northwest; quite possibly, it is composed of several smaller anticlinal structures. Cretaceous rocks in these folds are at an approximate depth of 1, 000 to 1, 500 m. South of the Eki anticlinal zone is the little-known Tsulukidzev syncline.

The Gudauty trough, situated between Gagra and Gudauty, is the western part of the Abkhazsko-Megrel region. Its natural northern boundary is the outcrop area of Cretaceous limestones. Two structural layers can be clearly distinguished within the trough; they are characterized by the same age and structure relationships as are the same layers in other sections of the Abkhazsko-Megrel region which have already been discussed. A singular feature of the Tertiary rocks of the Gudauty trough is the prevalence of coarse-grained clastics.

The Zvandrip anticlinal axis, composed of several smaller brachyanticlines with steeply dipping southern limbs and gently dipping northern limbs, passes through the central part of this trough. Maikop and Eocene rocks outcrop along the crest of this anticlinal axis is an extension of an anticlinal axis which is clearly reflected in the surface relief and which passes east of the Gudauty trough near a massive Cretaceous limestone outcrop. In the west, the Zvandrip zone is covered with Pliocene-Quaternary rocks and, apparently, plunges under the sea. It divides the Gudauty trough into a southern part (Baklanova syncline) and a northern part (Achandara syncline). In both synclines. second-degree anticlinal folds are present; like the folds of the Zvandrip zone, they are asymmetrical toward the south.

For a full description of the oil and gas prospects in the northeastern part of the Riono-Black Sea basin, it is necessary to mention the Adler structural trough which is located northwest of this region. The major part of the trough is situated between the lower courses of the Khoshup and Sochi rivers. The trough is filled with Upper Jurassic and Cretaceous carbonate rocks 200 m thick and marly-argillaceous rocks having a flyschlike appearance which have been assigned to the Paleogene. Within the trough, several anticlinal axes, developed farther east in the Gagrin range near Mesozoic outcrops, can be distinguished.

Many investigators distinguish here a northern or Golitsyn zone which strikes in a sub-Caucasian direction. The well-developed Berchil, Akhshtyr, Golitsyn, Akhun, and Bytkh brachyanticlines are included in this zone. Possibly, the Akhun and Bytkh, occurring in a linked position, are not part of the Golitsyn axis. They are separated from this zone by the Zvandrip syncline and could be extensions of the southern Gagrin anticlincal zone.

The Gagrin anticlinal axis extends from the Gagrin range to the Khoshup river basin where its crest begins to plunge. At the same time, the axis splits. The southern prong (the Chigiri anticline) is weakly developed and, apparently, plunges toward the sea in the Gantiadi region. The northern prong (Khoshup anticline) is clearly developed in the lower Tertiary and Cretaceous rocks. Its axis plunges to the west gradually, so that on the right bank of the Mzymta river, it is no longer reflected at the surface.

With the aid of seismic studies, it was possible to detect the southern Akhshtyr anticline at

the right bank of the Mzymta river. This anticline is situated at the extension of the Gagrin zone, and is a connecting link between the eastern uplift of this axis and the Akhun and Bytkh brachyanticlines.

Therefore, the following conclusions can be drawn:

1. The contemporary structure of the eastern part of the Riono-Black Sea basin was formed as a result of a whole series of tectogenetic episodes. Two sharply contrasting structural layers are differentiated: the lower, pre-Maotis and the upper, affecting Pliocene-Quaternary rocks. The lower is characterized by intermittent folding. The pre-Pliocene folding should be considered as the most important since it is prevalent throughout the Caucasus.

2. Individual uplifts can be grouped into extended anticlinal axes which are separated by wide synclines.

The basic features of regional tectonic structure which have been described here are of considerable in an evaluation of the oil and gas potential of the Riono-Black Sea basin. As has been mentioned above, this basin belongs to a group of oil- and gas-bearing in intermontane troughs, many of which contain some of the richest oil and gas fields, both in the U. S. S. R. and abroad.

Conditions favorable for formation of hydrocarbons have repeatedly occurred in the sedimentary beds of the northeastern part of the basin, particularly in the Chokraka, Karaganda, and Sarmata sandstones of the Maikop series in Gurgi. In Colchis and Abkhaziya, formations of this age are absent, but fractured carbonate rocks of Cretaceous age are of considerable interest.

Cretaceous limestone, found in Alpine intermontane troughs and in the folded limbs of marginal troughs, have recently been the objects of increasing and intensive exploration. In the northern Caucasus, fields have already been discovered (Karabulak, Achaluki) which contain major oil pools in these rocks. The exploration of Cretaceous limestones within the whole series of brachyanticlines would undoubtedly be of great interest both for those structures already known and for those which have been detected for the first time in this study.

It should be mentioned that the first attempts at oil exploration in Mesozoic rocks of western Georgia were not completely successful. Nevertheless, small pools of oil and gas were found in Upper Cretaceous limestones from wells drilled at the Chaladidi and Byrts uplifts (in Colchis and near Sukhumi, respectively). Indications of oil were repeatedly noticed in the Cretaceous limestones during drilling in the Adler region. These, as well as the numerous natural oil and gas occurrences related to these rocks, indicate the presence of oil and gas in the Mesozoic rocks of Colchis and adjacent areas.

In drilling, hydraulic fracturing, shooting, and frequent treatment of the rock with acid in promising intervals in the well would be employed.

In an evaluation of the prospects of the Tertiary rocks, particular attention should be given to the transitional zone from the Guri tectonic region to Colchis. On the southern limb of the Pechor anticline, Paleogene and Miocene rocks pinch out and are deformed; these include, farther south in the Supsa field a whole series of industrial-size pools in the oil- and gas-bearing strata. By the same token, favorable conditions exist for the formation of stratigraphic and lithologic traps.

An exhaustive evaluation of the oil and gas potential of western Georgia has not been attempted in this article. However, the facts and concepts presented here permit the evaluation of the eastern part of the Riono-Black Sea basin as a favorable area for the prospecting for oil and gas.

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RELIEF OF THE CRYSTALLINE BASEMENT IN THE SOUTHEASTERN PART OF THE SIBERIAN PLATFORM FROM AEROMAGNETIC SURVEY DATA[1]

by

V. A. Ozertsova, L. V. Polyakova, and T. N. Spizharsky[2]

• *translated by Research International Associates* •

ABSTRACT

The topography of the crystalline-basement of the southeastern Siberian platform is described; control for the contours is a total of 2, 000 depth determinations computed from aeromagnetic survey data. The interpretation suggested includes two principal structural elements: Aldan anteclise and Vilyuy syneclise. The north-dipping Aldan anteclise outcrops to the south. A number of minor troughs and folds are developed on major structures. -- Research International.

Basement structure of the Siberian platform is not as well known. Position of the Precambrian basement has been determined partially in the southern part of the platform from meager drilling data. Geophysical investigations were helpful in the study of these deep-seated structures, but these have been conducted over a limited area. The southeastern Siberian platform was covered by ΔT aeromagnetic survey; results of this survey were used to calculate depths to basement levels, then used to construct a contour map of the basement surface.

The first contour maps of the basement, constructed from aeromagnetic-survey data, were completed by T. N. Simonenko [1] for the western Siberian lowland. The method employed in that survey, with a few minor changes, was used to study the crystalline basement relief of the Siberian platform.

In the western Siberian lowland, the sedimentary-rock complex is practically nonmagnetic; magnetic rocks do occur in Paleozoic formations. Thus, only the smallest depth values calculated were used to compute surface relief. In the Siberian platform, magnetic rocks occur in the crystalline basement; locally, they appear in the overlying sedimentary mantle. During contouring of the basement surface, it was necessary to allow for this factor.

Depth of magnetic rocks was calculated from all ΔT anomalies in territory covered by the survey. High-accuracy aeromagnetic survey was undertaken by members of the Yakutsk geophysical expedition; work was completed by V. A. Ozertsova and L. V. Polyakova, of VSEGEI, and by T. S. Kutuzova, an engineer attached to the expedition.

For better results, calculation were made directly on magnetograms and, in certain instances, on 1:200, 000 scale graphic charts. The calculations were made according to the integral [1] and tangential [2] methods as modified by V. K. Pyatnitsky. For bodies of great horizontal extent, the method of higher derivatives [2] was employed. Approximately 2, 000 anomalies were measured. After introduction of necessary corrections relative to sea level the anomalies were plotted on a topographic map using a scale of 1:1,000,000. In this way, an approximation was obtained of depths at which magnetic-rock surfaces occur. On the basis of these data (also considering other geophysical methods and existing geologic knowledge), a schematic contour map was compiled for the southeastern Siberian platform basement surface.

Data were not sufficient for calculation of average error in depth determinations for this region. Such studies had been performed in western Siberian lowland survey where average error was determined to be $\pm$20 percent. Therefore, southeastern Siberian platform map was contoured at the following intervals: 0, $\pm$ 0. 5, $\pm$ 1, -2, -3, and -5 km. The -4 km contour is indicated by a dotted line, as are other contours determined from incomplete data (i. e. insufficient number of measurements). Zones of great depth (absolute readings below -7 km) are indicated.

To main structures, Aldan anteclise and Vilyuy syneclise, were identified in the southeastern Siberian platform, during compilation of the map. A transitional zone northwest of the syneclise, joins the Anabar anteclise. Data obtained from bore holes in Yakutsk and Olekaminsk regions; at Tuolba river, Russkoy stream, the Namana river mouth and Amga river; and, in Bilyuysk region, as well as analysis of other geologic information, make it possible to present an initial, approximate description of crystalline basement structural features.

In the Aldan anteclise, Archean crystalline rocks composing the basement plunge northward under Cambrian sedimentary formations; these, in turn overlain by Jurassic and Cretaceous rocks having considerable thickness in the Vilyuy syneclise and the Verkhoyansk foredeep areas. Although the crystalline basement gradually increases in depth, it has undergone two major uplifts; these, the Tuolbinsk and Amginsk uplifts, strike northeast and plunge in the same direction.

One drill hole in the Vilyuy syneclise, 2, 900 meters (m) deep, apparently had not penetrated

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[1]Translated from Relyef kristallicheskogo fundamenta Yugo-Vostochnoy chasti Sibirskoy platformy po dannym aeromagnitnoy syemki: Sovetskaya Geologiya, no. 5, p. 66-72, 1959.

[2]Vsesoyuzny Nauchno Issledovatelsky Geologichesky Institut.

beyond Upper Jurassic sediments; thus, roughly indicating the depth to basement syneclise to be of the order of several kilometers. Mesozoic formations are underlain by a thick, Paleozoic sequence of Cambrian through Carboniferous formations Analysis aeromagnetic-survey data revealed definite regularity in depth distribution of the southeastern Siberian platform basement surface (fig. 1).

complex.

A series of local depressions and elevations with an amplitude of approximately 1 km, develop to the north of the Aldan anteclise on the gently dipping basement surface. This anteclise is bordered on the west by Berezov foredeep, a deep-seated structure forming an embayment in the uplifted portion of the basement. Along the

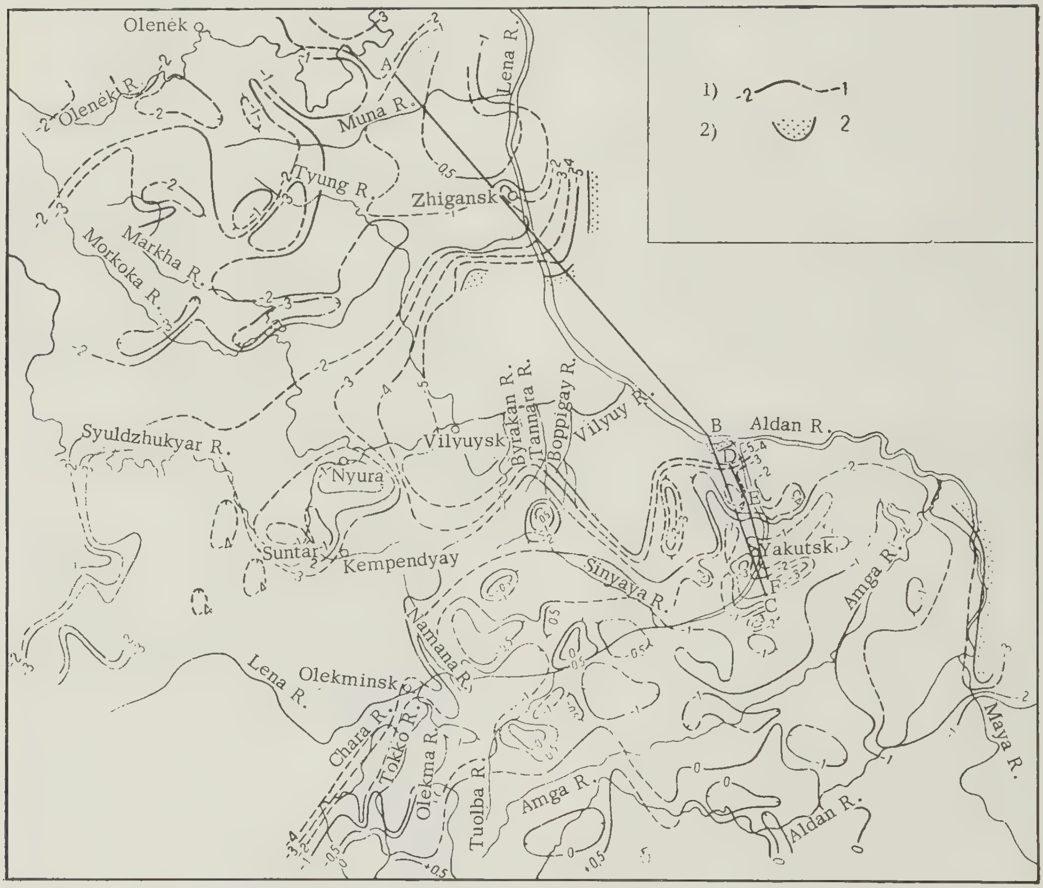

FIGURE 1. Schematic contour map of the southeastern Siberian platform basement surface (compiled by Ozertsova and Polyakova from the Yakutsk geophysical expedition aeromagnetic-survey data). 1) contours showing the assumed basement surface (dotted line indicates contours based on incomplete data), 2) zone of absolute elevations - 7 km and deeper.

In the Aldan anteclise region, the basement surface dips gently northward from positive, absolute elevations to depths of 3 to 5 km. Deepening of the basement surface was noted also in the eastern sector of the anteclise from Amga river toward Verkhoyansk range. Under the east-trending Aldan river (near the 135° - 136° meridians), the basement is deep (absolute elevations of -7 km). This zone in the Verkhoyansk fold region is a geosynclinal trough bordering Aldan anteclise on the north and east. Anomalies in this region indicating magnetic rocks to accurate shallow depths have been disregarded; they obviously denote surface magnetic inclusions in the Verkhoyansk rock

1 km contour, this embayment can be traced from the Namana river mouth almost of that of the Tuolba river, including a sector in the middle and lower reaches of Olekma and Tokko rivers. To the east of this embayment, according to magnetic data, the northeast-striking Tuolbin uplift can be easily traced. The absolute elevations of the basement surface are approximately -1 km, and in certain sectors, -0.5 km, near the middle reaches of the Tuolba River. An uplift having absolute elevations above the sea level (O) was formed along the northeast extension of the embayment. The uplift is not reflected by surface structure, but, judging from the shallow depth of basement

rocks at Sinyaya river mouth, it should be near the surface in this part of Aldan anteclise.

The Aldan anteclise crystalline massif penetrates the Vilyuy depression in the form of two large prongs; the axis of one passes through the 124° meridian. In the central part of this prong a local, almost isometric, uplift has been detected. At this point, absolute elevation of the basement is above -0.5 km; its relative height above the rest of the basement is 1.5 km. It is interesting to note that tributaries of Vilyuy, Byrakan, and Bappigay rivers and of Lena and Sinyaya rivers originate at this prong. The Tannara, a Lena river tributary, has its source in the central uplift. The second prong, striking north-northeast, is situated north of the 62° parallel between the 127° and 130° meridians. Here, two uplifts were noted: one, with an absolute elevation of more than -2 km, strikes northward; the second strikes north-northwest. In this region absolute elevations of the crystalline basement range from -1 to -2 km. The uplifts are not expressed at the surface; their existence was discovered in examination of aeromagnetic-survey data.

As was revealed by detailed ΔT aeromagnetic survey, the crystalline basement structure is much more complex in the northeast part of Aldan anteclise. A series of local relief forms develop over a considerable area of the basement surface. In this region, absolute elevations range from -1 to -2 km; the surface dips toward the northeast, gently at first, then more steeply. A ridge striking east in Yakutsk region and to the northeast, has, in its eastern sector, absolute elevations above -1 km; it is accompanied by individual uplifts of approximately -0.5 km absolute elevations. Lack of sufficient data makes it impossible to determine whether any continuity may exist among the individual uplifts. An arcuate depression, convex to the southwest, and located on the southwest side of the ridge is below -3 km absolute elevation in its central part. Still farther southwest, a ridgelike uplift, also arcuate, with absolute elevation above -1 km has been noted.

The complex structure of the basement surface in the Yakutsk region was caused by fracturing along the Verkhoyansk foredeep margin where individual blocks of crystalline rock were subjected to movements varying in amplitude. This is indicated by the shallow depth (500 m) of crystalline rocks in Yakutsk region. In this sector of the Siberian platform, aeromagnetic survey has revealed a large anomaly (intensity: 1,000 gammas), traceable for some distance. Two maxima striking northeast were detected. The anomaly originates south of Yakutsk and continues parallel to the Lena river. Further on, the anomaly is less pronounced; it disappears completely in the Vilyuy syneclise and then reappears on its northern side. A weaker anomaly 25 km to the east, and parallel to the stronger one, has been observed. These anomalies were recorded on the map; obviously, such large anomalies are caused by major faults in the platform.

Calculations have shown that magnetic rocks causing anomalies toward Vilyuy depression, plunge to great depths. In Yakutsk region, the lowest, absolute basement-surface elevation is 1 km; at 62°40'N, -4 km. Farther northwest the basement rises slightly, but plunges steeply at 63°N, to -5 or -7 km approximately. The anomaly can be traced along maxima which slope downward rather gently; it disappears at 63°30'N. According to calculations described below, magnetic rocks plunge to a depth of approximately 12 km. Near 65°N, the anomaly reappears. Absolute elevations in the Kyundudey river region are as great as -8 km; toward the northwest, absolute depth of the basement surface changes gradually. At 65°45'N, the basement surface rises rather sharply (dip: from 3 to 4°) and again at 67°20'N, it rises gradually to -0.5 km elevation.

Many readings along the Yakutsk anomaly facilitated construction of a cross section (fig. 2)

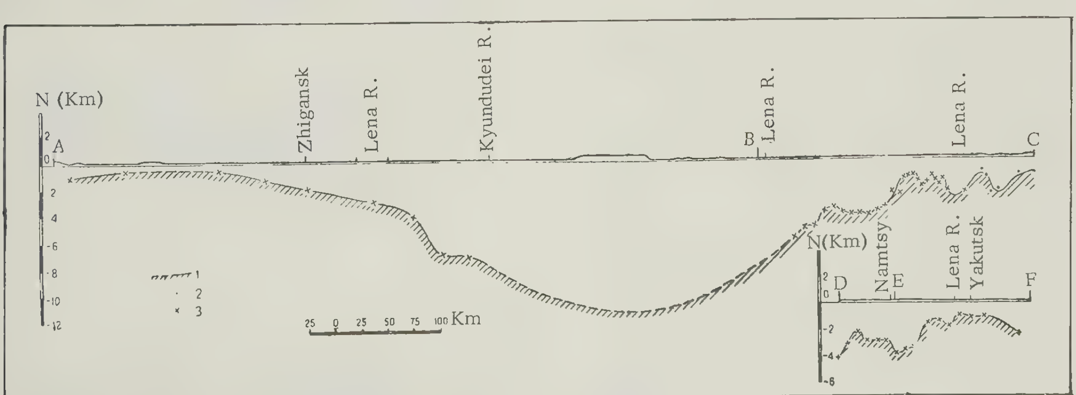

FIGURE 2. Cross sections ABC, DEF (fig. 1)
1) assumed crystalline-basement surface, 2) calculated values for absolute elevations of the basement surface, 3) absolute elevations of basement surface averaged from four values.

depicting all previously mentioned features of basement relief. A similar cross section was prepared for the area east of Yakutsk. Comparison of the sections will reveal similarity in all basement surface relief features.

The magnetic field is not strong in Vilyuy syneclise area; therefore, the usual methods could not determine basement rock depth. However, if it is assumed that the central syneclise basement is composed of the same rock as the flanks, some idea of minimum depth can be obtained by extrapolating individual anomalies from syneclise margins where the last readings were made. Calculations showed depth in the center of the syneclise to be approximately 8 km.

At syneclise margins, the basement surface plunges steeply, particularly along the northern margins. Quite possibly, a large fault occurs in this region (66°N, 122°-126°E); part of the syneclise may have been down thrown along it to great depths. Such a conclusion would not contradict geologic information because Vilyuy syneclise borders Verkhoyansk marginal trough near the 66°N parallel.

Southwest of Vilyuysk, an uplift in the basement surface as high as -4 km was observed; in this area, the Vilyuy syneclise is a trough trending southwest toward the Lena river. Compound structures occur here. To the west, near Suntar and Syuldzhukyar rivers, the basement rises sharply to -2 km absolute elevation; along Vilyuy river, between Suntar and Nyurba, absolute elevations are -1 km. The nature of the uplift is not clear; possible, a block of crystalline rock is situated in this region. North of the block, no significant variations were noted in basement-surface relief.

An east-striking depression of -3 km or greater absolute elevation was observed near the Morkoka river mouth. The depression, 30 to 60 km wide, trends northeast near the 118° meridian and extends as far as the Tyung river. Botuobinsk ridge separates the depression from Vilyuy syneclise; basement depth in the ridge area is about -2 km. An analogous depression, striking northeast, has been noted to the north; north of Tyung river strike direction changes to north, then to northwest, north of Muna river.

In the region northeast of Syuldzhukyar, aeromagnetic data revealed a series of magnetic anomalies caused by rocks located at or near the land surface (trap rock is widespread in the region); data obtained from these anomalies were disregarded.

North of Vilyuy syneclise an uplift extends from the right bank of Lena river northwestward to the Olenëk river area. Actually, basement relief in the area is more complex because a series of uplifts comprise its basement structure. These uplifts form Prilensk ridge, separating Olenëksk trough from Verkhoyansk foredeep. The highest elevations were observed north-northwest of Zhigansk where the basement surface depth is 0.5 km [Tr.: -0.5?]. A small embayment 20 km wide and striking south, occurs in this uplift.

East of the uplift, the basement surface plunges steeply toward Verkhoyansk foredeep where depth of the crystalline rocks is greater than -7 km; this zone of great depth is located near Verkhoyansk range.

Data presented indicate that a structural map of the southeastern Siberian crystalline basement, based on magnetic data, agrees with known geologic data, and as well, largely complements it. The result is fuller understanding of structures comprising the basement of the Siberian platform.

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TECTONIC STRUCTURE OF THE WESTERN BLACK SEA REGION[1]

by

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• *translated by Research International Associates* •

ABSTRACT

The geologic structure and history of structural development in the western part of the pre-Black Sea depression during the Paleozoic and Mesozoic are discussed. The author concludes that the so-called "pre-Black Sea depression" is not an area of prolonged downwarping. Thus, the term "pre-Black Sea depression" should be replaced by pre-Black Sea block."--Auth.

STRATIGRAPHIC SCHEME FOR THE WESTERN BLACK SEA REGION

The oldest sedimentary formations of this region are polymictic arkosic sandstones outcropping along the shores of the Dnestr (Kosoutsa region) and found by drilling in the Odessa region and in many localities in both northern and southern Moldavia. Their thickness reaches 100 m. Kortsenshteyn, as well as Lungershausen, assigned these formations to the Cambrian [10]. A. G. Zavidonva tentatively considers them to be Reefian [Precambrian] [8].

Unconformably above them lie thick strata of tawny, dark-brown shales and sandstones interbedded with gray sandstone. These beds were deposited in a shallow, fresh-water basin. Zavidonova assigns the lower part of these beds to the Reefian and the upper part to the Cambrian. The boundary between the Proterozoic and the Paleozoic in this rather homogeneous section is established very tentatively; it should be more realistic to lower this boundary to the arkose-shale contact where Kortsenshteyn has discovered an angular unconformity [10]. The total thickness of the Reefian and Cambrian increases in a west and southwest direction from the Ukrainian crystalline massif. In Podolye, it is estimated at 250 to 300 m; in Ungeny on the Pruta river, 455 m; and in the Odessa region, 706 m. East of Odessa, in the direction of the basement outcrop, the lower Paleozoic rocks pinch out. In the Azov region, Cretaceous beds rest directly on the Precambrian basement (fig. 1).

A thin bed of calcareous sandstone (1.5 to 2 m) contains an Ordovician fauna. It outcrops along the Dnestr and has been located in several drill holes in Bessarabia. Zavidonova is of the opinion that Ordovician sediments are almost completely absent in the Paleozoic section and that this represents a prolonged hiatus in sedimentation.

Silurian rocks, overlying the eroded Cambrian, are composed of marine sediments containing a rich fauna of brachiopods, bryozoans, ostracods, and corals. The following stages can be distinguished: Llandoverian, predominantly microcrystalline, argillaceous limestones; Wenlockian, dolomites and dolomitized limestones grading upward into pure limestones containing a rich fauna; Ludlovian, gray, fine-grained argillites containing a scanty fauna. Silurian beds outcrop in Podolye and have been recognized in several drill holes in the Moldavian S. S. R. and the Odessa region. Along the western slope of the Ukrainian crystalline massif, these beds can be traced in a relatively narrow belt; their thickness may be as great as 400 m. Along the southern slope of the massif, the Silurian section is incomplete. The upper argillaceous-shale part of the section is absent (Ludlovian stage) and the carbonate series pinches out east of central Moldavia. The thickness of Silurian limestones in the Odessa region is only 18 m [8].

The Silurian limestones characterize a normal marine basin which, however, became considerably restricted and quite shallow during the Middle Silurian. This is indicated by the presence of lagoonal sediments, including dolomites and anhydrites, deposited during the Wenlockian. Paleozoic rocks younger than Silurian are absent in the pre-Black Sea depression; they occur only in Podolye, along the western slope of the Ukrainian crystalline massif, and in the Hercynian foredeep of the Keletsko-Sandomir chain (fig. 1).

Devonian, Carboniferous, and supposedly Permian rocks 3,000 m thick are developed in the upper Paleozoic fold region located northwest of the ancient Dobrudzha nucleus (fig. 2).

Triassic sandstones, limestones, and shales

[1]Translated from O Tektonicheskoy strukture zapadnogo Prichernomorya: Moskovskogo Obshchestva Ispytateley Prirody, Byulleten, Otdel Geologii, v. 34, no. 1, p. 61-71, 1959. The first section of this paper, a historical review, is not included in this translation.

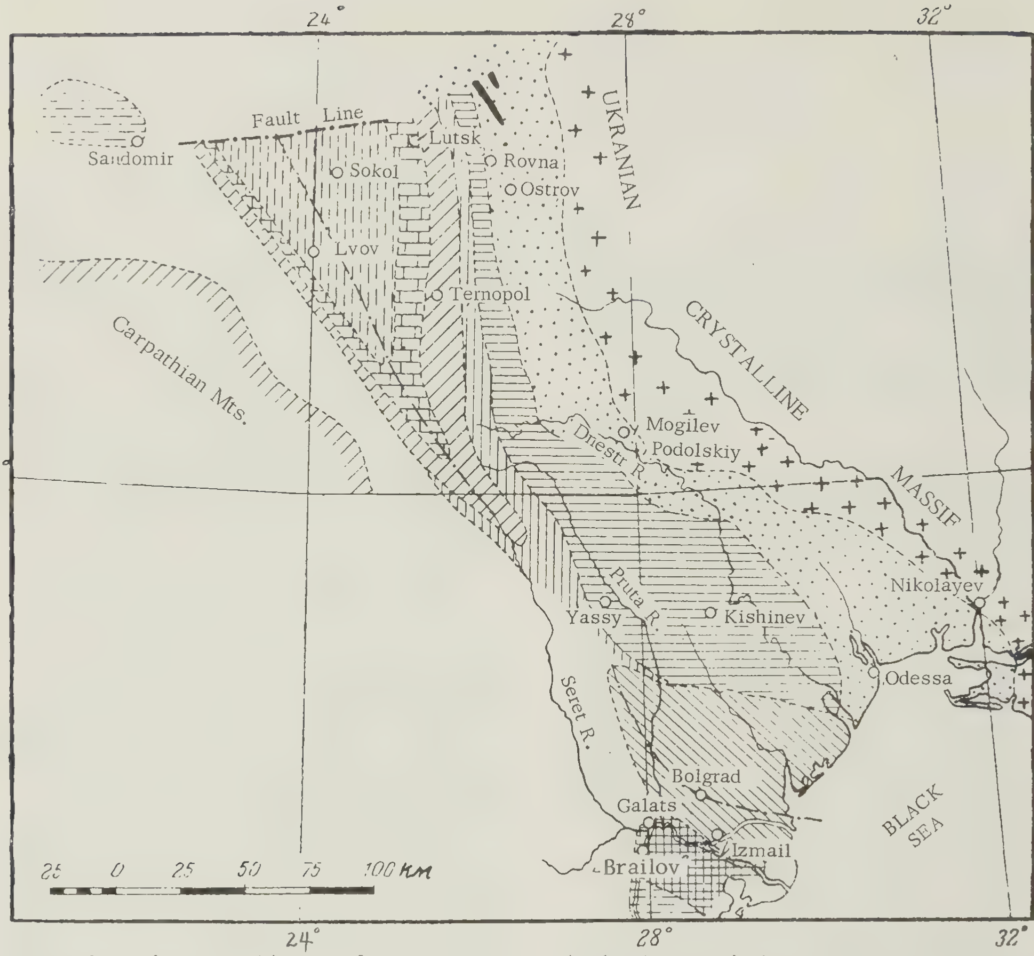

FIGURE 1. Paleogeographic map of pre-Cretaceous rocks in the pre-Black Sea and Lvov depressions. Compiled by M. Ya. Rudkevich, 1952.

Jurassic

Carboniferous

Upper and Middle Devonian

Lower Devonian

Silurian, shale beds

Silurian, Carbonate beds

folded mesozoic and upper and middle Paleozoic of Dobrudzha

Cambrian

outcrop of the lower Paleozoic nucleus, Keletsko-Sandomir chain and Dobrudzha

Volyno-Podolye Paleozoic extrusives

axes of the Lvov trough and the Dobrudzha foredeep

over 1,500 m thick are distributed in northern Dobrudzha where they cover Paleozoic rocks and form a system of tight folds truncated by thrust faults. In the Moldavian S. S. R. and the Odessa region, all these [Triassic?] sediments are absent. At the southern slope of the Ukrainian crystalline massif, Cambrian and Silurian rocks (and in the Melitopol region, the Precambrian basement) are directly covered by Cretaceous rocks (and west of Odessa, by Senomanian rocks). Thus, during a very long period of time, from the end of the Silurian to the beginning of the Senomanian, the northern Black Sea area was a region of degradation.

In southern Bessarabia, a relatively small

sector has been discovered from drilling which contains thick Jurassic sediments. Within this section, the Lower, Middle, and Upper divisions have been distinguished. The Lias and Dogger are characterized by interbedded argillaceous and argillaceous-calcareous shales. The Malm consists predominantly of argillaceous sediments. The total thickness of the Jurassic beds is 2, 500 to 3, 000 m. The Jurassic rocks were deposited in a typical foredeep, as indicated by the "displaced complex," characteristic for structures of this type (according to the terminology of Muratov [15]. Tithonian beds are represented by a separate sequence of red clays and sands interbedded with thick layers of gypsum and anhydrite. The deposition of salt-bearing strata is a characteristic feature of marginal troughs during the last stage of their development.

After deposition of the Kimmeridgian trough sediments, there was a hiatus in sedimentation which lasted until the beginning of the Upper Cretaceous. Upper Cretaceous rocks are widely distributed throughout the area, except for southwestern Bessarabia. The axial line of the Upper Cretaceous platform depression is parallel to the Dobrudzha chain, and considerably north of the Jurassic trough axis. The southwestern limb of the Cretaceous depression coincides with the deepest zone of the Jurassic beds. Upper Cretaceous rocks in the axial part of the depression (Odessa region) consist of thick carbonate beds: limestones, marls, chalk, and calcareous sandstones. Senomanian-Turonian beds are present throughout the depression. Younger rocks, Santonian and Campanian, occur only in Odessa and pinch out toward the limbs of the depression. The maximum thickness of the Upper Cretaceous is not greater than 450 m; the minimum thickness, according to drilling data from the region of Ungeny on the Pruta river, is not less than 20 m.

The Senomanian-Turonian basin of the western Black Sea region was an extensive bay of the Cretaceous sea located in the present Crimean steppe and the Azov region. Thick beds of Upper Cretaceous sediments, over 1, 500 m, were deposited here.

Paleogene beds, consisting of marls and clays interbedded with sandstones and sands, overlie various horizons of the Upper Cretaceous. In southern bessarabia, they cover Jurassic rocks and, in the northeast, on the southern Bug river, they lie directly on the crystalline basement. Carbonate-argillaceous rocks and characteric of the Eocene; grass-green clays and sands are assigned to the lower Oligocene. The Paleogene basin in this region was a relatively narrow bay in the eastern part of the pre-Black Sea depression. The Paleogene trough strikes east. The maximum thickness of Eocene-Oligocene rocks has been determined in the Odessa region where it is 300 m. The Paleogene depression is displaced somewhat to the south in relation to the Upper Cretaceous trough.

The history of the Neogene basins in the western Black Sea region is closely related to the tectonic development of the eastern Carpathians. During the lower Miocene and for a good part of the middle Miocene, thick flysch and salt-bearing beds were deposited in the Carpathian foredeep [Tr.: marginal trough?]. During this time, the Black Sea region was an area of degradation. Only towards the end of the middle Miocene (Tortonian), after considerable subsidence of the Hercynian-Kimmeridgian fold system (the remnants of which are the Sventokshish mountains, the Keletsko-Sandomir chain) and Dobrudzha, the western margin of the platform subsided and formed the base of marine basins. Along this margin, another independent structure formed. It should be regarded as an upper Miocene-Pliocene Carpathian terminal foredeep, developed on the platform base [17].

STRUCTURAL SCHEME AND BASIC STAGES IN STRUCTURAL FORMATION OF THE WESTERN BLACK SEA REGION

The structural scheme for the western pre-Black Sea depression (fig. 2) reflects the basic stages in its geologic development. The following structural elements, are shown in the scheme: 1) the lower Paleozoic platform depression situated between the slope of the crystalline massif in the northeast and the gently folded, downwarped, northeastern limb of the Dobrudzha anticlinorium; 2) the Mesozoic (Triassic-Jurassic or only Triassic) Dobrudzha foredeep; 3) Upper Cretaceous intraplatformal depression developed over the lower depression; 4) Paleogene intraplatformal depression developed on the Cretaceous depression and the outer limb of the Jurassic trough; 5) the outer limb of the upper Miocene-Pliocene Carpathian terminal foredeep. Among the larger second-order structures developed on the Jurassic trough is the Kagyl-Pandakly ridge which separates this trough into an outer and inner zone.

The history of tectonic development in the Black Sea region can be traced from the beginning of the Paleozoic. In the lower Paleozoic, a geosynclinal region existed in Dobrudzha and, possibly, in the adjacent narrow belt of southern Bessarabia; terrigenous sediments of relatively small thickness were deposited north of this region on the gentle slope of the platform.

During the Caledonian tectogenetic stage (possibly in the Ordovician), an embryonic mountain chain was formed in the internal zone of the present Dobrudzha and Sventokshish

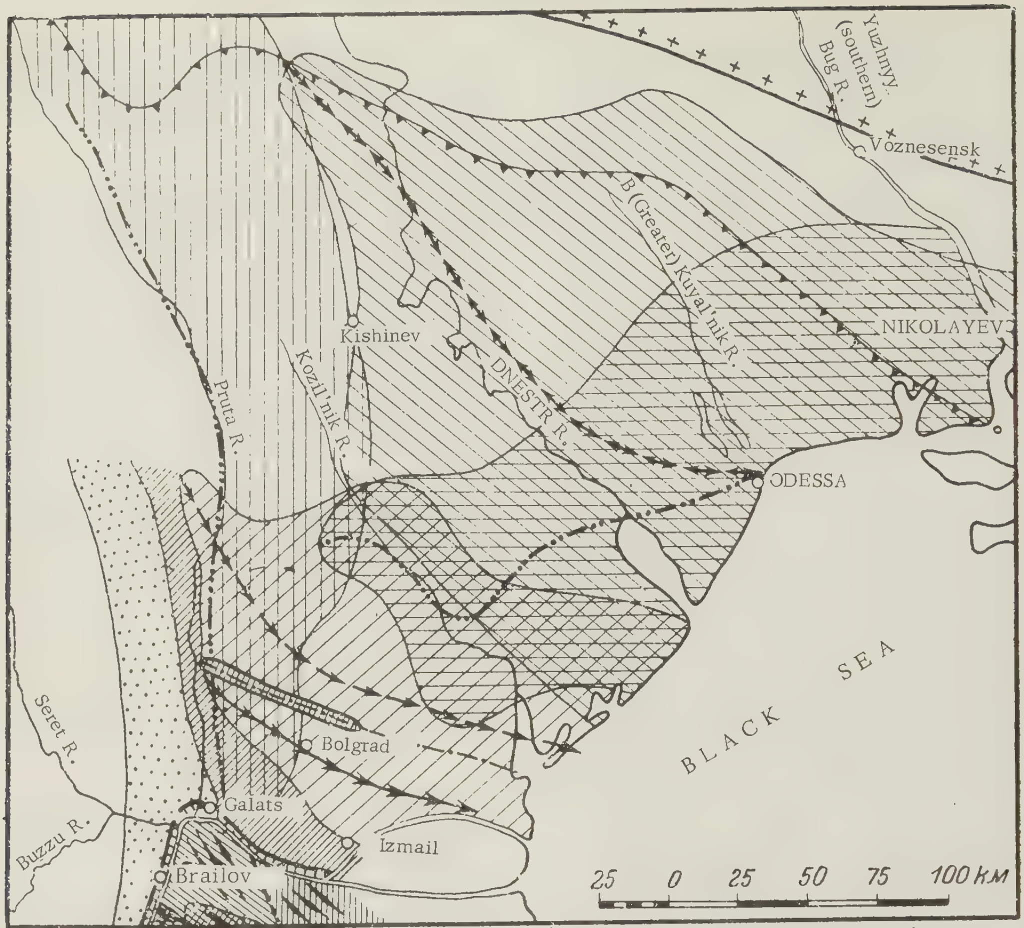

FIGURE 2. Structural scheme for the western part of the pre-Black Sea depression

I. The margin of the pre-Black Sea depression

- southern boundary of the Ukrainian crystalline massif
- northern boundary of the exposed Dobrudzha Mesozoic-Paleozoic structure
- lower Paleozoic or Proterozoic nucleus of Dobrudzha
- region of upper Paleozoic folding
- region of Mesozoic folding
- Babadar syncline (Cretaceous sediments)
- main lines of disruption in Dobrudzha
- proposed extension of the Dobrudzha chain, buried in the center of pre-carpathian middle Miocene trough
- belt of shallow folds--shallow zone of the northeast limb of the Dobrudzha anticlinorium
- axes of the major anticlinal folds

II. Main tectonic structures

- northern limb of the lower Paleozoic platformal depression (in the region the thickest lower Paleozoic beds, from 300 meters and over)
- Mesozoic (Triassic-Jurassic) Dobrudzha foredeep
- Paleogene interaplatformal depression, and outer margin of the Jurassic trough
- outer limb of the upper Miocene terminal Carpathian foredeep
- Cretaceous intraplatformal depression, developed on the downwarped slope of the Ukrainian crystalline massif, on the base of the lower Paleozoic depression and the outer margin of the Jurassic trough

Legend continued next page.

III. Axial lines of the depressions and troughs

inner zone of the Mesozoic trough

outer zone of the Mesozoic trough

Cretaceous depression

Paleogene depression

upper Miocene and Pliocene trough

IV. Secondary structual elements

Kagul-Pandakly ridge, situated in Jurassic rocks, and its proposed extension

mountains, as well as in the belt between them (in the Prutsko-Serets watershed). A considerable meridional sector of the Dobrudzha-Keletsko-Sandomir anticlinorium was not subjected to further folding and became fused to the margins of the platform. During Hercynian folding, the Caledonian structures were further developed as a consequence of geosynclinal growth. The uplifted Keletsko-Sandomir chain was incorporated into the platform and a Hercynian foredeep was formed in the Lvov region. This foredeep, according to A. A. Bogdanov, pinches out to the south [3].

Geosynclinal conditions were maintained only in Dobrudzha where folding ceased at the Triassic-Lias boundary. Subsequent orogenic movements caused the formation of the Jurassic foredeep. This structure fades out toward the northwest, in the direction of the Caledonian fold zone. Quite possibly, this trough fades out to the east, in the direction of the basement outcrop, between Nikolayev and Melitopol.

At the end of the Jurassic, Dobrudzha and the marginal trough were incorporated into the platform. Upper Cretaceous and Paleogene synclines were subsequently developed on the platform; their formation, however, is related to late Kimmeridgian and early Alpine tectogenesis in mountainous Crimea.

CONCLUSIONS

As examination of structural development in the western pre-Black Sea depression makes it possible to arrive at several conclusions. For a very long period of time, from the beginning of the Paleozoic to the Quaternary, the territory between the outcrop of the Ukrainian crystalline basement in the north, the shores of the Danube, and the Black Sea in the south, the valleys of the Pruta and the southern Bug rivers in the west and the east, respectively (an area including almost all the western part of Arkhangelsky's pre-Black Sea depression) is actually a region of relative uplift. The idea that this region was subjected to prolonged and continuous subsidence is due to the covering of the Black Sea region by a thick, almost horizontal mantle of Neogene sediments which conceal the subsurface structures.

During the known stages of geosynclinal development, sectors bordering the ancient platform on the west and south were subjected to a certain degree of downwarping for short periods of time. However, after the close of each tectogenetic cycle in the geosynclines, this territory once again became a region of uplift.

In the combined section of this region, almost all geologic systems are present. However, throughout the area of western Black Sea, each sector shows a hiatus in sedimentation. These interruptions lasted throughout almost all the Ordovician, during the middle and upper Paleozoic, for considerable intervals in the Mesozoic, and for the better part of the Tertiary. Thus, the territory of the western Black Sea region has been a shallow arch throughout all geologic time, submerged only during periods of maximum transgression by ancient seas from the west, south, and east. Moreover, the direction of the transgressions differed at different times.

Areas of prolonged downwarping and intensive sedimentation existed along the margins of this arch, beyond the area which is referred to as the pre-Black Sea depression. Only the Kimmeridgian orogeny in Dobrudzha caused deep subsidence of a narrow belt along the southern margin of the platform and the deposition of thick layers of Jurassic sediments. However, even here, during the formation of the Dobrudzha foredeep, the time of intensive submergence was relatively short, encompassing only the Jurassic.

The western part of Arkhangelsky's pre-Black Sea depression was developed on the slope of the Ukrainian crystalline massif. The latter, with the Polessky Precambrian basement ridge and the Baltic shield, forms, according to Arkhangelsky, part of a huge meridional horst in the crystalline base of the Russian platform. This horst is characterized by continuous uplift above the rest of the platform throughout its geologic history.

The data presented above on the geologic structure of the western Black Sea region form a basis for the rejection of the term "pre-Black Sea depression" (at least, for the western part of the region). The term "pre-Black Sea block" would be more appropriate. Under this term should be included the southwestern marginal zone of the Russian platform where the deep-

seated crystalline basement (at a depth of 1,500 to 1,800 m) is covered by a relatively thick mantle of rock dipping at a small angle toward the Black Sea and the Danube delta.

In the southern part of Moldavian S. S. R., the pre-Black Sea block borders the Kimmeridgian Dobrudzha marginal trough. In the northwest, it fuses with the Podolye block; in the west, it is connected to the Carpathian marginal trough which, in its base, contains the "Caledonian bridge" uniting the Dobrudzha and Sventokshish (Keletsko-Sandomir) chain, and a marginal belt of the Russian platform.

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SOLUBILITY OF SALTS OF SOME ELEMENTS IN SUPERCRITICAL WATER VAPOR[1]

by

K. M. Feodotyev and V. K. Shlepov[2]

• *translated by Michael Fleischer* •

ABSTRACT

The intermediate and unstable stages of hydrothermal and pneumatolytic processes are little understood; they have been studied indirectly through research on solubility of salts of certain metals in supercritical water vapor. It has proved very difficult to devise apparatus that can withstand experimental conditions requiring high temperatures and pressures, and, which will permit separation of the gaseous phase for measurement of its dissolved-salt content. The authors describe an autoclave of their design which they have used to investigate solubilities of certain metal salts at temperatures as high as 430°C and pressures of 375 atmospheres. Pressure is produced in the autoclave by heating water vapor to the required temperature. The autoclave, whose total volume is 19.5 cubic centimeters, consists of two chambers connected by a narrow channel; a needle valve can be operated by external control mechanism to block the channel, separating the two chambers. Thus, supercritical vapor can be isolated in one chamber before it is cooled and condensed. Cooling and condensation can be brought about independently in either chamber, so that the experiment can be carried to its conclusion within the autoclave. Gaskets usually are made of nonferrous metals and as such are a possible source of contamination to experimental materials; however, through precision grinding of contact surfaces, the need for gaskets was eliminated. The first experiments were made on alkali-chloride solutions to determine chemical analysis methods. Experimental criteria were based on comparison of the initial volume of solution to the final volume of solution in each of the two chambers, and on the ratios of two final volumes to the volumes of the two chambers. Alkali-chloride saturation of supercritical solution was approximately 0.5 grams per liter; degree of saturation was found to have only slight dependence on concentration of the original solution. Lead-chloride solubility in supercritical solution, derived from preliminary data, was approximately 2.0 grams per liter. These studies indicate that some heavy-metal salts, as well as the lighter alkali salts, can migrate in gaseous solution at pressures found at considerable depths. The resultant solutions are stable in a narrow range of temperatures and pressures; under changing conditions, the salts crystallize, liberating water in the process. -- D. D. Fisher.

At present we are able to observe in Nature only some products of hydrothermal and pneumatolytic processes, that, as a rule, are from the final stages. All intermediate and unstable stages cannot be observed; they do not appear in nature. One must conjecture about intermediate stages of the process, based on data obtained by the study of physical-chemical systems on solubility of certain salts.

We have begun to study hydrothermal processes by investigating solubility of certain salts of metals in supercritical water vapor. Our paper is devoted to the first results obtained in our experiments.

In the literature there are few, broad systematic studies devoted to the supercritical solubility of inorganic salts. This is due, apparently, to difficulties of experimentation under conditions requiring high temperatures, i. e., above 370°, and pressures of 300-400 atm. Under these conditions water shows a strongly corrosive action on the walls of vessels, gaskets, and other fittings. At temperatures above 250°, the use of glass is not possible because it is transformed into hydrous silicates; decomposition of test tubes in the autoclave proceeds with great speed. Consequently, systems containing water must be studied in test tubes made of special materials; the apparatus, therefore, is complex. There is no universal apparatus for study of the supercritical state. In each new work we find original constructions and sometimes interesting methods of doing the experiments.

The first works of Hannay and Hogarth on critical and supercritical phenomena of organic substances were little noted. The more systematic studies of Centnerszwer and coworkers [6, 7, 8] were concerned with study of the effect of dissolved material on the critical-temperature magnitude of the solvent. They established

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[1]Translated from Rastvorimost soley nekotorykh elementov v nadkriticheskom vodyanom pare: Pyatogo Soveshchaniya po Eksper. i Tekhn. Mineral. i. Petrogr., Trudy, Akademiya Nauk SSSR, 1958, p. 230-236.

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that the critical temperature of organic solvents increases regularly with increasing concentrations of dissolved material.

Schröer [12], working with aqueous solutions, found critical temperatures of solutions to be higher than the critical temperature of pure solvent. The method of study involved heating sealed glass ampules filled with solution, and determining the temperature of disappearance of the meniscus; this occurs at the critical temperature. Somewhat later, the problem of critical temperature of salt solutions was studied by N. I. Khitarov and L. A. Ivanov [3, 4]. With L. E. Rotman [5], they also used for this purpose a tube autoclave, sealed at both ends without solution in it, and balanced on a prism.

The tube, filled to one-third volume with the solution being studied, is heated to the temperature at which it again arrives at the equilibrium state; this occurs when the critical temperature is attained. The liquid (solute and solvent) transforms into the gaseous state and the tube autoclave assumes a horizontal position. In these experiments there were occasions when complete levelling was not observed. The authors drew the conclusion that critical phenomena existed; part of the solution transformed into the critical state, but the remainder consisted of a viscous liquid.

Incomplete levelling of the tube is explained more correctly by the precipitation from the solution of crystals, onto the walls of part of part of the autoclave; this occurs when the liquid is in equilibirum with the supercritical phase. No doubt, these experiments of the authors demonstrated, as a first approximation, that critical temperatures of the solutions were higher than the critical temperature of water and depend on concentration and nature of the dissolved material.

In their later works, Khitarov and Ivanov showed that critical temperature increases regularly with increase in dissolved-material concentration in solutions of simple composition; the simple relations disappear, however, in multi-component solutions.

The first systematic studies on the capability of gases to transport a solid phase were made by Dutch scientists Van Nieuwenburg, Blumendal, and Van Zon [13, 14, 15], involving a series of experiments in the area of hydrothermal syntheses of various minerals. Apparatus used by Nieuwenburg, Blumendal, and other authors to study supercritical solutions, consisted of an autoclave, i. e., a closed vessel in which the solution of the salt under investigation was heated, and from which, by various methods, there were drawn off samples of the gaseous solution heated above the critical temperature.

Usually, separation of the gaseous phase was accomplished by its condensation either inside or outside the autoclave. Condensation of the gas phase inside the autoclave has been accomplished by many investigators (e. g., Syromyatnikov [2], Gillingham [1]). Preparation of the solution takes place in the autoclave; the substance is stirred along with water in it. The condensate was collected in a crucible hung in the upper part of the autoclave. In some cases there was put into it a weighed amount of solid "collector"; in this material there were formed various silicates from matter transported in the gaseous phase.

The apparatus (used by the authors mentioned above) suffered from substantial deficiencies: During cooling, the solution has a tendency to boil, which might involve, at its lower critical temperature, the fall of solution droplets into the crucible. It is possible also that it would cause equalization of concentration, on cooling, as a consequence of different vapor pressures above condensate and solution. Insufficiently intensive ability to condense tends to give an insufficient amount of condensate in the crucible. This is caused also by nonuniform cooling of the autoclave.

Ölander and Liander [11] studied the system $NaCl$-H_2O by the method of condensing the gaseous phase outside the autoclave. In this case, samples were removed from the autoclave through a special capillary; then, the condensate was collected and analyzed. As a deficiency of this method one must note the possibility of an error caused by discharge of salt crystals by the gas-forming solution at the moment the exhaust valve is opened, and, as well, by change in pressure in the autoclave when the sample is removed.

Concurrently, solubility of KCl was studied by Jasmund [10]. The work was carried out in an autoclave of 1 liter (L) capacity, designed for temperatures up to 500 ^{o} and for pressures up to 300 atm. Samples were withdrawn by means of a special sampler: At the time of removal of the sample the pressure is lowered; this is a defect in the method.

Jasmund obtained the following results: at 400^{o} to 255 atm, solubility was 1042 mg/L KCl; at 450^{o} and 299 atm, 580 mg/L; at 475^{o} and 305 atm, 432 mg/L; at 500^{o} and 300 atm, 278 mg/L. Attention is attracted to the magnitude at the point at 400^{o} and 255 atm: It exceeds significantly the magnitudes of values at 450^{o} and 500^{o}.

In our studies we used an autoclave of special construction; the necessary pressure produced by water vapor heated to the given temperature, is not measured, but calculated. Our autoclave permits us to isolate from the original solution, without complex devices, the

supercritical vapor in one chamber of the autoclave before cooling and condensing it. This autoclave consists of two cylindrical communicating vessels placed on a single axis. The point of communication in a channel of 3 mm diameter is provided with a needle valve, operated from outside by means of a diaphragm. This arrangement permits one to break the connection between the vessels at the necessary moment, and to carry out independently the condensation in both vessels without changing temperature and pressure inside the apparatus.

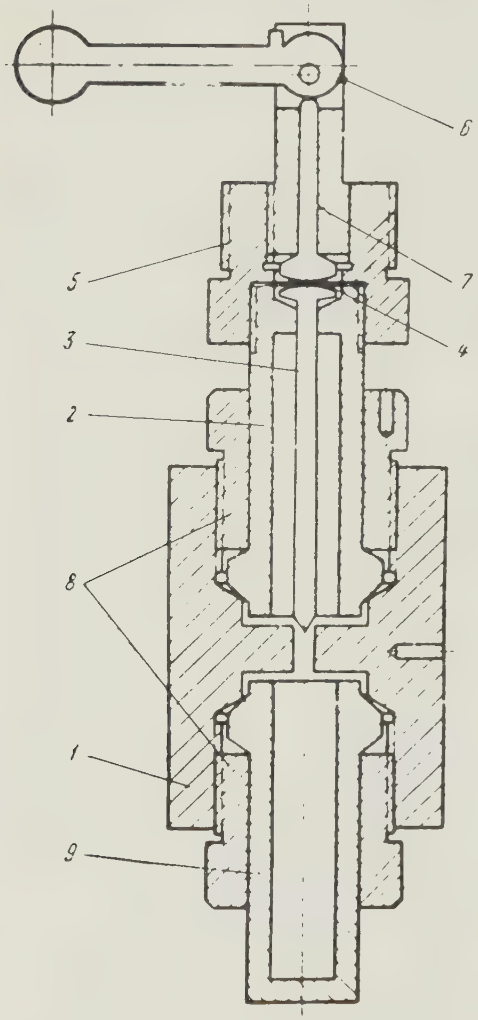

FIGURE 1. Schematic diagram of the autoclave for obtaining supercritical solutions

The construction of the autoclave is represented in Figure 1. It consists of the housing (1) in which are fitted two sockets - a lower (9), and upper (2), with the needle (3). The sockets are held in the frames by the nuts (8). On the upper socket is assembled the arrangement controlling the needle valve; it consists of the diaphragm (4), the rod (7), the nut (5), and the lever arm with eccentric (6). One end of the needle is oval shaped to prevent its cutting the diaphragm; at the other end, the needle has a 60^{0} angle point. Both cylinders (upper and lower) are linked by a channel drilled along the axis of the autoclave. At a specific moment this opening is covered by the special needle by means of the control arrangement.

The autoclave assembly is completed without gaskets: This is possible thanks to the presence of highly ground conical surfaces at the edges of the sockets. The absence of gaskets made of nonferrous metals makes the apparatus more universal and eliminates contamination of the solution by extraneous materials.

The volume of the autoclave equals $19.5\,cm^3$. In Figure 2 the autoclave is shown assembled;

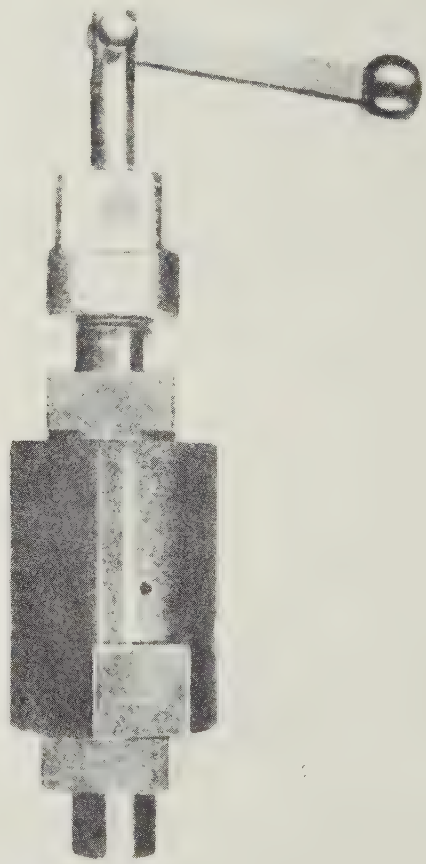

FIGURE 2. The autoclave; general view.

and in figure 3, disassembled.

For heating the autoclave there was made a special furnace (fig. 4). It has a metal tube with openings (1), in which are wound the nichrome heating element (2). The tube with the winding is placed in an iron housing filled

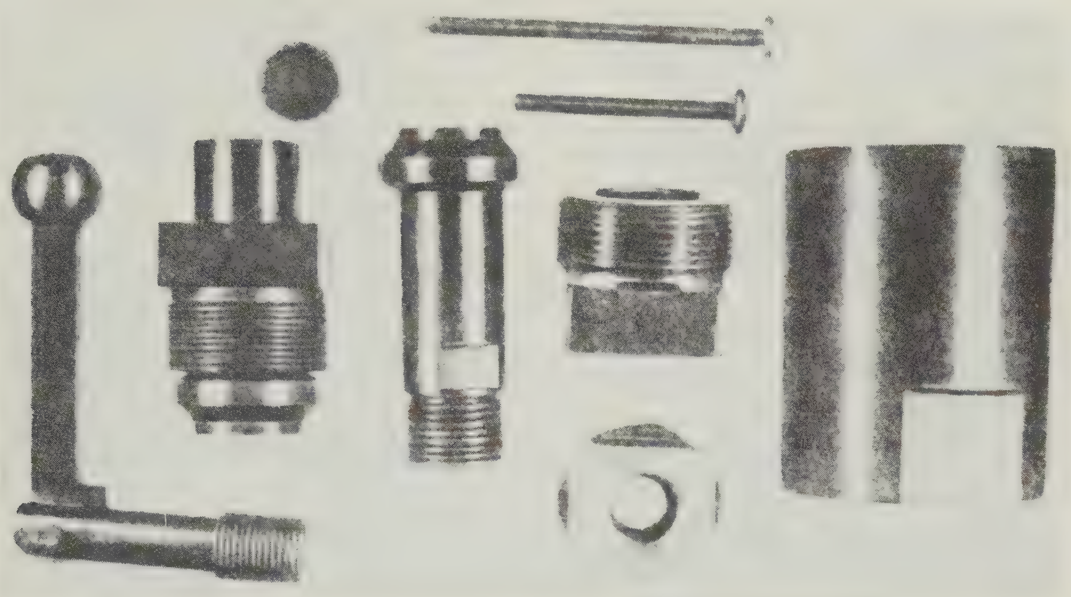

FIGURE 3. The autoclave; disassembled

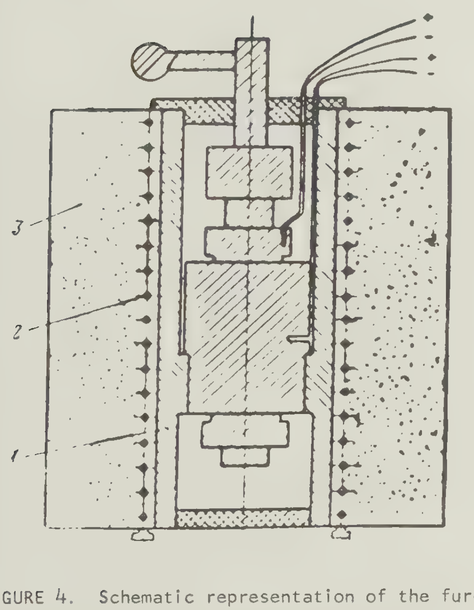

FIGURE 4. Schematic representation of the furnace for heating the autoclave

with heat-insulating material (3). Regulation of the temperature was accomplished with the auto-transformer LATR-1.

During heating, the temperature was controlled by two chromel-[kopel? (transliteration: Kopelevymi)] thermocouples. The hot junction of the thermocouple was placed in a special cylindrical hole drilled in the frame and the nut of the autoclave (fig. 4). The T.E.D.S. thermocouple was recorded on a self-recording millivoltmeter.

When all preliminary experiments on construction of the autoclave were completed, we obtained the work of K.S. Copeland, J. Silverman, and S. W. Benson [9]. They also had used an autoclave with an inside valve, but controlled by a spring. Their construction permits one to isolate the supercritical phase and to condense it separately. The autoclave constructed by these authors is very complex.

In the autoclave that we constructed, we have carried out experiments to determine solubility of potassium, sodium, and lead chlorides.

For these experiments, the solution of given concentration was placed in the lower container of the autoclave. This container was connected to the assembled autoclave by opening the needle valve. Then, the autoclave was placed in the furnace and slowly heated to the desired temperature; experiments were continued for 48 hours or more, because equilibrium was not approached in shorter periods of time.

After the heating period, the needle valve was closed and the autoclave cooled so that supercritical vapor condensed in the upper vessel, and the original solution remained in the lower.

The first experiments were made with alkali-chloride solutions; these solutions were used to determine the methods of chemical analysis. The experiments were considered successful if the sums of volumes of the solutions in both

vessels equalled the volume originally placed in the autoclave and, if the ratios of both volumes corresponded with the ratio of volumes of the vessels.

Pressures was determined from total volume of the autoclave (equalling 19.5 cm^3), the degree of filling and, by using the diagram of Van Nieuwenburg and Blumendal [14]. This calculation is possible because the low concentrations of salt solutions obey the laws discovered for pure water.

The solutions recovered from the autoclave were analyzed for Cl ion for the alkali solutions and for Cl ion and Pb^{2+} in the case of lead chloride solutions.

The data obtained for alkali salts are given in Table 1. These data show the saturation of supercritical solution to depend but little on concentration of the original solution and to be about 0.5 g/L.

TABLE 1. Alkali-chloride solubilities in supercritical vapor

Salt	Concentration of solution mol/L	Degree of filling	Temperature °C	Pressure atm	Time kept hours	Solubility g/L
KCl	0.3	0.33	430	375	2	0.516
KCl	0.3	0.30	430	365	2	0.492
NaCl	0.1	0.30	420	350	2	0.453
NaCl	0.1	0.30	420	350	5	0.514

TABLE 2. Lead-chloride solubility in supercritical vapor

Concentration of original solution	Degree of filling	Temperature °C	Pressure atm	Time of exposure hours	Solubility g/L
Saturated	0.30	395	280	46	2.037
at	0.20	395	260	68	2.038
	0.30	420	350	48	1.696
20°	0.30	420	350	42	1.696

In Table 2 are given data on lead-chloride solubility. We are able to cite data for two temperatures and a small range of pressures in the autoclave. As a result we have supercritical solutions containing up to 2.0 g/L lead chloride.

The studies made indicated that at pressures corresponding to significant depths, salts can migrate easily in the form of gaseous solution. From these studies it also follows that not only alkali salts, but significant amounts of heavy-metal salts as well are transported easily in gaseous solution.

The resultant gaseous solutions are stable in a very narrow range of supercritical temperatures and pressures. Data obtained are insufficient to explain the entire picture of migration, but one may foresee the behavior of salts under these conditions. In particular, changes in conditions cause salts to crystallize out of the gaseous solutions, liberating water. Thus, there may occur local salt concentrations, and, too, there may be created conditions favorable to reaction of aqueous solutions of the enclosing rocks.

CONCLUSIONS

1. A special autoautoclave has been designed and constructed for obtaining supersolutions, thus permitting experimentation of temperatures up to 600° and to pressures of 450 kg/cm^2.

2. A method has been devised for obtaining supercritical solutions.

3. First results have been obtained on solubility, under supercritical conditions of KCl, NaCl, and $PbCl_2$.

Concentrations of salts in gaseous solutions for KCl and NaCl attain 0.5 g/L; and for $PbCl_2$ 2.0 g/L.

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NEW DATA ON THE DEPOSITION OF CRYSTAL SUBSTANCE ON CAVITY WALLS OF LIQUID INCLUSIONS[1]

by

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• *translated by V. L. Skitsky* •

ABSTRACT

The concentrations of aqueous solution from which quartz, feldspar, topaz, tourmaline and other minerals crystallize during the hydrothermal stage, is important to an understanding of pegmatite formation. Two opposing theories have been advanced on solution concentration: 1) Pegmatitic minerals separate from highly concentrated solution, without marked change in concentration, by gradual cooling. 2) Pegmatitic minerals separate as a result of flow and of renovation of the exhausted contents of solutions; this need is based on low solubility of silica in pure water. Study of liquid inclusions in minerals reveals that separation of hydrothermal minerals is known to occur from aqueous solutions heavily saturated with alkaline-halide salts, carbonates, borates, and free carbonic acid. From observations made on secondary liquid inclusions in topaz samples from pegmatites, it was found that one-third of the inclusion-cavity volume was occupied by the gas bubble and the remainder of the volume, largely, by small crystals of several solid phases. Inclusion contents could not be completely homogenized, because they exploded at 400° - 450° C; homogenization required temperatures above 500° C. Flattened inclusions, formed by healing of cracks parallel to the (001) cleavage plane, were examined. At room temperature, the included bubble was disk like; on heating to temperatures of 180° - 200° C, the bubble contracted revealing beneath it a circular crescent-shaped depression, probably an indication that crystal substance had been deposited on inclusion-cavity walls. Accordingly, crystal substance precipitated out after entrapment of solution in the cavity because redeposition occurred around the bubble; this could have been possible only after the solution had been completely enclosed and subsequently cooled. To determine the original amount of substance entrapped, measurements were made of inclusion-cavity volume, thickness of substance deposited within the cavity (found to be about 2 percent of inclusion-cavity height), and depth of crescent-shaped depression. From these data it was found that up to 2 percent volume of the topaz substance remained in dissolved state at relatively low temperatures. Deposition traces were found on walls of sufficiently flat inclusions where a large part of the wall surface was blocked by a flattened bubble; presence of these conditions was required in order to detect the deposited layer and measure its height.

In order to understand the nature of the pegmatitic process, the greatest importance must be attached to the concentration of aquaeous solutions from which quartz, feldspars, topaz, beryl, tourmaline, and other minerals crystallized during the hydrothermal stage. Two opposite viewpoints exist on this subject: One presupposes separation of pegmatitic minerals from a highly concentrated solution without changing it markedly, merely as a result of gradual cooling. This evolutionary hypothesis, advanced by A. E. Fersman, [1], was based on comparative studies of a vast amount of material gathered during mineralogical examination of pegmatitic deposits. The other viewpoint envisages separation of minerals such as quartz, feldspar, topaz, and others from solutions having, as a result of their protracted flow and a continuous renovation of exhausted contents, low concentration of substances that enter into composition of these minerals. There exist also intermediate viewpoints.

One proof , given to support the need for renovation of the exhausted solution, usually is said to be the low solubility of silica in pure water. It is forgotten, strangely enough, that we now know from study of liquid inclusions in minerals separation of quartz, topaz, and other minerals, soluble with difficulty in pure water, has occurred in an aqueous solution heavily saturated with alkaline-halide salts, carbonates, borates, and containing a considerable percentage of free carbonic acid. It is perfectly obvious that this highly concentrated and complex dissolving medium, very adequately named by N. P. Yermakov [2] the "hydrothermal brine" ("gidrotermalnaya rapa"), must have behaved at high temperatures and pressures entirely differently than pure water.

Insofar as it can be considered obvious that liquid inclusions in minerals constitute preserved remnants of the medium from which these minerals were crystallized, the best and, most probably, the only conclusive proof in support of either of the viewpoints, under discussion here is to be obtained by detailed study of the liquid inclusions themselves and of composition of their contents. In the case of certain high-

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[1]Translated from Novyye dannyye ob otlozhenii Veshchestra kristalla na stenkakh polosti zhidkogo vklyucheniya: Doklady, Akademiya Nauk, SSSR, Novaya Seriya, Moscow, v. 82, no. 5, p. 765-768, 1952.

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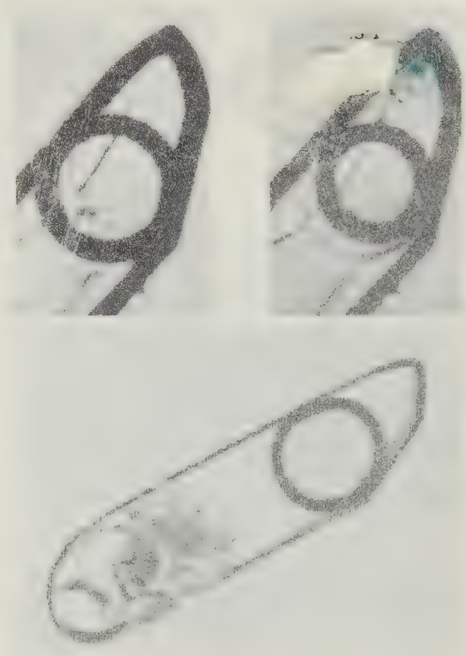
temperature inclusions in quartz and topaz, one of the authors [3] advanced the first such proof by calling attention to the toothed, crystallographically ill-balanced contour of the inclusion walls; around these could be seen the former closed boundary of the inclusion. However, doubt was expressed promptly that this internal toothed contour of the inclusion cavity had been formed by deposition from solution already wholly isolated in the inclusion [4]. It was suggested that deposition had occurred gradually from a changing solution before the inclusion cavity had closed. Evidently for the sake of caution, the possibility was recognized that a thin layer called "coating" also could have been deposited on the cavity walls by solution completely locked within it.

Without reverting here to causes of toothed contours in inclusions and to origin of a hem around some inclusions, we shall now consider entirely new evidence proving conclusively that a notable amount of topaz substance is still separated from the wholly isolated mother solution and deposited upon the cavity walls of topaz inclusions even after considerable lowering of temperature.

Our observations have been made on secondary liquid inclusions in topaz samples from pegmatites. The gas bubble in these inclusions occupies at room temperature about one third of the entire inclusion-cavity volume. A considerable part of the cavity is occupied by small crystals of several solid phases; these phases have separated from the enclosed solution and are reentering it in definite sequence during careful heating (see fig. 1A). Later we shall give special attention to determination of these solid phases; at present it will suffice to state that, in addition to several easily soluble solid phases, one finds as well in all inclusions of this series solid phases difficult to dissolve, more particularly in oligoclase; we ascertained its presence by direct determinations. It is not possible to achieve complete homogenization of inclusion contents, because they explode at temperatures as low as 400° - 450° C. Apparently, homogenization would occur above 500° C.

Experiments requiring heat were conducted on a converted heated microscope (which we constructed); and changes in the inclusions were recorded by means of sectional kino-photomicrography. We selected for observation considerably flattened inclusions, formed by the healing of a crack [5, 6] disposed parallel to the (001) cleavage plane in topaz. At room temperature in this type of the gas bubble, is shaped like a flat disk [see fig. 1B]. After heating these inclusions it was observed that at temperatures 180° - 200° C the gaseous-phase bubble, in contracting, reveals a circular depression beneath which looks like a flat crescent (see fig. 1C).

A B



C

FIGURE 1

A: A liquid inclusion in topaz with several solid phases, photographed at room temperature; magnification 134X.

B: Part of inclusion (A) in detail, at room temperature; 120X.

C: Same as B, at the temperature of 420° C. 120X

In some inclusions it is possible to see two, three, and even more such crescents (see fig. 2) displaced relative to one another at their

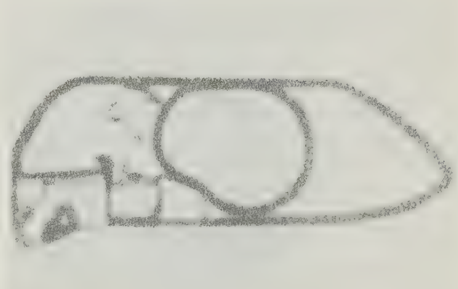
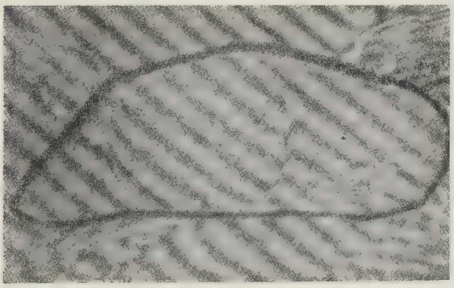


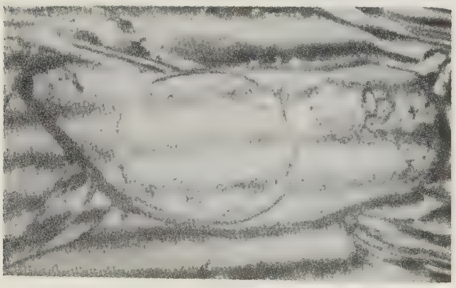
FIGURE 2. An topaz inclusion showing several crescents under the gas bubble, which has shifted to the side. Photographed at room temperature; 335X.

centers and of various diameters. Depressions of corresponding form are found also under crystals of solid phases separated from the inclosed solution. We succeeded in gathering

both upper and lower walls of the inclusions studied f ... samples which exploded from ove... Both opposite halves of the inclusions ...ed the same crescents in corresponding positions; i. e., one facing the other (see fig. 3 A and B).



A



B

FIGURE 3. A microinterferometric picture of the surface of a basal plane of the cavity from the inclusion shown in Figure 1. Photographed in mercury green line (λ = 546 mμ) illumination.

A: The first half of the cavity; 95X

B: The second half of the cavity; 93.5X

Occasionally, the gas bubble is displaced from its position over the crescent by pressures from crystals of easily soluble solid phases, separated from solution. In this case the edge of the crescent can be seen also at room temperature (see fig. 2). Usually, at room temperature, however, the broad, dark contour of the gas bubble fully conceals beneath itself the entire circumference of the crescent.

It is difficult to view the described crescents, observed under the gas bubble, as anything other than the result of deposition of the crystal substance on all inclusion-cavity walls except the circular area covered by the disklike gas bubble or areas under crystals of some solid phases difficult to dissolve. There can be no doubt whatever that this separation of the crystal substance has occurred after complete isolation of the solution in the closed inclusion cavity; inasmuch as the crescents show deposition of substance around the gaseous-phase bubble, whose very appearance in the inclusion is possible, under normal conditions, only after closing of the system and cooling it to a certain degree. Incidentally, the moment when the topaz substance ceased to precipitate and the solution was practically exhausted has been, apparently, determined by size of the external diameter of the crescent, which corresponds to an entirely definite gaseous-phase volume; i. e., to an entirely definite temperature, in any case, somewhat below 200° C.

Obviously, it was especially important to determine, at least to approximate, the amount of substance which became separated from that portion of the solution locked in the inclusion cavity. This determination proved possible with sufficient accuracy in the case of samples, whose inclusions can be opened in one or another way. Opening of topaz is facilitated by the existence of excellent cleavages. To determine the approximate value of the percentage ratio between the amounts of deposited substance and of enclosed solution, it is sufficient in the case of the very flattened inclusions which we studied to measure: 1) thickness of the layer of substance deposited on cavity basal planes not covered by the gaseous-phase bubble, and 2) the thickness of the solution layer in the flat inclusion, i. e., height of the inclusion cavity. Determined in this way, the percentage of separated substance, will be somewhat smaller, obviously, than the actual percentage, because it is necessary to add to it also that portion of substance deposited on perimetric side walls of the cavity. However, it would be quite impossible to detect the thin layer deposited on these vertical walls of the inclusion cavity by looking at it from the front; and, still less possible to measure this layer in that its boundary is entirely masked by optical effects.

We made our measurements on a sample that had split along its cleavage plane into two flat halves as a result of explosion from over-heating. The splitting revealed several inclusions, disposed in the plane of a healed crack paralleling the cleavage. Height of the inclusion cavity was determined by measuring depth of both halves of the cavity separated by the split. Height measurement was made by means of a microscope equipped with a 90 X objective (magnification: 63 X); the process involved taking the difference of readings on the micrometer screw, by focusing first on the cavity bottom and then, on the cleavage plane of the split forming the upper edge of the cavity. The accuracy of such a measurement is usually not

greater than 0. 5 μ. Table 1 gives average values for 10 measurements. Heights of the four cavities under investigation ranged from 24 to 40 μ. the bubble occupied the space (defined by contours of the crescent) formed by its blocking action.

Number	Height of first half of inclusion	Height of second half of inclusion	Height of total cavity of inclusion	Depth of crescent in first half of inclusion	Depth of crescent in second half of inclusion	Total thickness of deposited layer	Percentage ratio thickness of deposited layer to inclusion height
	μ	μ	μ	μ	μ	μ	
1	17. 8	9. 2	27. 0	0. 24	0. 24	0. 48	1. 79
2	19. 4	21. 2	40. 6	0. 54	0. 57	1. 11	2. 74
3	21. 8	17. 0	38. 8	0. 27	0. 27	0. 54	1. 39
4	14. 6	9. 6	24. 2	0. 22	0. 22	0. 44	1. 83

Measurement of crescent depths and consequent determination of thickness of the substance layer deposited on basal planes of the inclusion cavity were made by the "microinterferometric" method. Under the microscope, using mercury green line illumination ($\lambda = 546$ mμ), a photograph was taken of first-degree interference occurring on the basal plane of the inclusion cavity (see fig. 3 and 4). Crescent depth was determined then from the displacement of the interference stripes at crescent edges. Because boundary walls of the crescent are sufficiently sloping, it usually was possible to trace the course of a stripe disposed along the crescent border. Accuracy of measurements by this method, under the conditions of our experiment, equals about 0. 1 of the stripe width and, for the wave length of the mercury green line corresponds to about 0. 03 μ. Interferometric measurements indicated that a layer of 0. 22 to 0. 57 μ had been deposited on the basal planes of the inclusions studied outside the crescent areas.

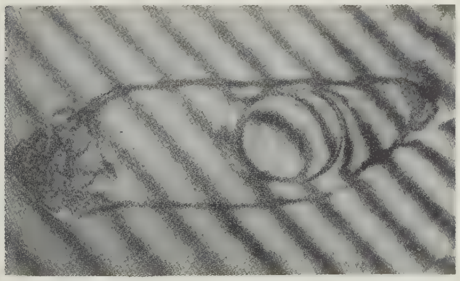


FIGURE 4. A microinterferometric picture showing traces of several consecutive positions of the gas bubble; 162X.

Table 1 shows the sum of layer thicknesses deposited on both basal planes of the inclusion cavity to constitute about 2 percent of height of the cavity itself or, what is the same, of thickness of the solution layer in a flattened inclusion. Consequently, up to two percent volume of the topaz substance was still in dissolved state at relatively low temperatures at which

Our new observations, described herewith, on liquid inclusions in topazes from pegmatites, thus show conclusively that lowering of temperature induces a notable quantity of topaz substance to became separated from the enclosed part of the solution. This separation demonstrates that considerable concentration of hydrothermal solutions continue the "pure line" of the pegmatitic process.

It is not to be doubted that similar traces indicating deposition of dissolved substance in places not blocked by the gaseous-phase bubble will be found also in topaz inclusions from other deposits, as well as in clusions contained in other minerals. Let it be remembered however, that these traces can be observed only on the walls of sufficiently flat inclusions, where a considerable part of the wall surface is blocked by the flattened, gaseous-phase bubble, this blocking action creates the specifice conditions necessary to detection of the deposited layer and to measurment of its height. Of course, deposition of substance on cavity walls has been taking place also in inclusions having isometric form. The gaseous phase bubble, in this case spherical, did not touch inclusion cavity walls and, thus, did not prevent deposition of crystal substance on these walls during cooling. Blocking action in such inclusions could have been produced only by separated crystals of solid phases difficult to dissolve. However, detection and measurement of the depressions formed under such crystals is possible only in exceptional cases.

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DISTINCTIVE FEATURES OF THE HEALING OF A CRACK IN A CRYSTAL UNDER CONDITIONS OF DECLINING TEMPERATURE[1]

by

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• *translated by V. L. Skitsky* •

ABSTRACT

Ordinarily the ratio by volume, of liquid to gaseous phases entrapped in secondary inclusions formed by healing of a single crack in a crystal, is constant. Under these conditions, it is possible to determine temperature of mineral formation by examining the contents of a single inclusion. Occurrence of wide variation in the ratio of gaseous to liquid-phase volumes can occur in inclusions along a singlehealed crack; however in this case, determination of mineral-formation temperatures by this method are rendered invalid. Differences in crack formation of healing are not apparent where the phase volume ratio shows wide variation or lack of it; it is obvious in both cases that the inclusion had formed simultaneously. The temperature range involved appears untenable with distribution of inclusions and of types of inclused phases. Several explanations have been given for the occurrence of this wide variation of phase-volume ratios along a single crack; for example: Variation could have occurred as a result of penetration of an initially nonhomogeneous solution. Observational data has provided the solution to this problem: Crack healing was rapid under high temperature conditions; it was found that solution could be isolated in pockets along the crack before significant temperature decrease. Because changes in cavity shape are a longer process, larger inclusions can remain relatively elongated. With decreasing temperature, the gas bubble forms in all inclusions along a healed crack including non altered cavities. Two inclusions will form by the sealing off of an elongate inclusion: the content of one inclusion will be homogeneous, and of the other, a gas bubble. A sodium saltpeter crystal was used in the experiment, under decreasing temperature conditions. Initial crack healing occurred at 100°C; subsequently, the system was cooled to room temperature; and, then, change of form was studied. Presence of single inclusions of widely varying phase-volume ratios in a healed crack indicates a low temperature decrease during changes in cavity shape and during differentitation which tends to occur in larger inclusion cavities. In order to determine homogenization temperature, phase-volume ratios should be constant in adjacent inclusions; an average determination can be made if a sufficient number of inclusions are sampled. The author concludes that this formation process is possible also in primary inclusions, as a result of their differentiation and during their change in shape, in a matrix solution under conditions of decreasing temperature. -- D. D. Fisher.

Ordinarily all the inclusions that formed in one healed crack and develop a gaseous phase after decrease in temperature are characterized by the same ratio of their liquid - phase to their gaseous-phase volumes. Only in these cases, then, can individual inclusions from the total assemblage in a healed crack serve for various investigations aimed at determining temperatures of mineral formation. We often encounter in various minerals (quartz, topaz, beryllium, fluorite, and others), however, healed cracks containing liquid inclusions (notwithstanding what appears to be obviously simultaneous formation) of great diversity in their phase content. Even though these inclusions are located precisely, (it should be stressed), in the same healed crack, not in several cracks formed at different times, this diversity occurs.

Thus, some cause must account for presence of different ratios between volumes of included phases from the same thin section, other than the existence of several healed cracks dating from a different time. It is known that failure to understand fundamental reasons for such differences, as were observed soon after the work of G. C. Sorby, has had initially a very unfavorable effect on development of geologic thermometry methods [1].

There is often exceptionaly wide variation in ratios between volumes of included phases. It has been observed that some inclusions, from one healed crack, consisted almost entirely of the gaseous phase; whereas other, adjacent inclusions were almost entirely filled by the liquid phase. Moreover, not infrequently transitions had occurred from one extreme to the other, having diverse ratios between volumes of phases (see fig. 1). If solid phases also are formed in the inclusions, their relation accordingly, can vary as does the ratio of gaseous to liquid phases (see fig. 2). In other respects, healed cracks containing such inclusions do not differ materially from those with inclusions characterized by constancy of the ratio between volumes of phases.

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[1] Translated from Osobennosti zalechivaniya treshchiny v kristalle v rezhime snizhayushcheysya temperatury: Doklady, Akademiya Nauk, SSSR, Novaya Seriya, Moscow, v. 87, no. 6, p. 957-960, 1952.

[2] Institute of Crystallography, U.S.S.R. Academy of Sciences, Moscow.

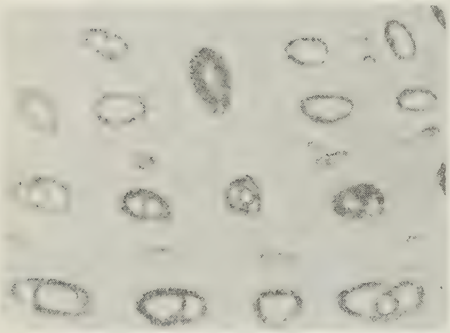

FIGURE 1. Aquamarine. Liquid inclusions in a healed crack, almost parallel to the base, 240X. A general view of this slide is given in figure 9 of the paper [2] .

FIGURE 2. Quartz from quartz porphyry; 181X.

At first glance, the irregularity of distribution found within a healed crack with inclusions of varying content, would alone seem to exclude the possibility that successive formation (i. e. closing) of the inclusions had occurred under conditions ranging from very high temperatures for inclusions of preponderantly gaseous phase, to low temperatures, for inclusions of predominantly liquid phase. At the outset we also rejected as improbable that occurrence of such complex combinations of inclusions in a healed crack resulted from healing process effected by an initially nonhomogeneous solution, i. e., a boiling solution containing a finely dispersed gaseous phase, which had penetrated into the capillary crack. Formation of a nonhomogeneous medium, to heal a crack, also could be supposed to result from capillary condensation of the dissolving agent; this is actually observed, not infrequently, in healing of dry cracks in such hydroscopic minerals as halite. However, this supposition must be rejected in the case of most pegmatitic and, especially, hydrothermal minerals.

It proved possible to find the solution to the question concerning origin of those inclusions which have varying relations between the volumes of the liquid and the gaseous phase, and which occur in the same healed crack. We reasoned from the observational data on development of spontaneous healing in crystal cracks [3]: The evidence showed that the crack-healing process can develop relatively [fast?] at high temperatures, and that isolation of the matrix solution between threads of restorative dendrites can occur in inclusions even prior to significant temperature decrease in the surrounding medium. However, change in shape of the inclusion cavities towards an equilibrated form [Tr. Probably means negative crystal type of cavity.] requires a much longer time. At the moment of significant lowering of temperature, there always can remain among the relatively large inclusions those which have a very nonequilibriated shape, e. g., elongated or ramified. With decrease in temperature a gaseous-phase bubble forms in all inclusions along a healed crack, including as well, those inclusions still nonequilibriated. Further, in the course of tying-up the latter type of an inclusion, two inclusions will be formed: One of these will be homogeneous in content and the other will contain the gas bubble. The same division can occur also in distribution of the solid phases, had they separated during cooling. In such differentiation ratios resulting between volumes of phases in daughter-inclusions can become extremely varied.

During the change in thermal regime, the differentiation process in nonequilibriated inclusions might have continued in each of the stages for a long time; this could have further complicated the picture of ratios between volumes of included phases. In a healed crack, where transformation of inclusions had developed under conditions of gradually decreasing temperature, there will occur inclusions having normal ratios between the volumes of phases, corresponding to the entire range of temperatures, and, those having volume ratios abnormally increased in favor of the gaseous phase.

Confirmation of accuracy of the explanation advanced by us for the origin of such inclusions, was obtained experimentally from our special tests on healing of cracks in a sodium saltpeter crystal under decreasing-temperature conditions. More precisely, the initial period of healing was observed at a high temperature (100°C.); subsequently, the specimen was cooled to room temperature and a study was made of the successive change shape in nonequilibriated inclusions. Successive stages in differentiation of two elongated inclusions and in formation of inclusions having different ratios between gaseous and liquid-phase volumes are shown in the series of micro-photographs (see fig. 3).

Figure 3a shows the inclusions, formed by the healing of a crack at 100°C. and, subsequently, just cooled to room temperature. In each inclusion, either isometric or elongated, a gas bubble formed; its volume was propor-

a
b
c
d

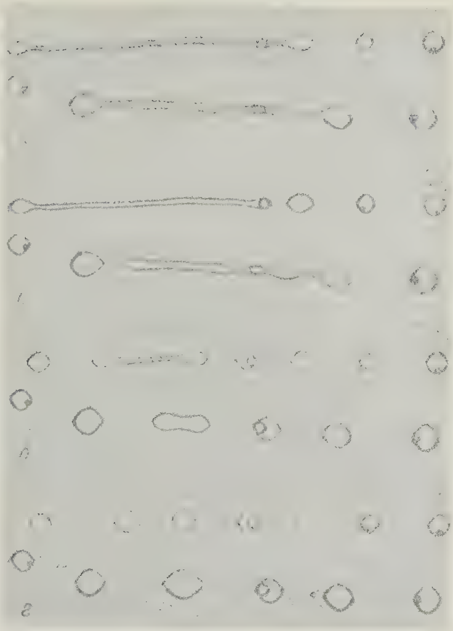

FIGURE 3. Sodium saltpeter. Formation of inclusions having anomalous ratios of the volumes of the liquid and the gaseous phase; 162.5X.

a: photographed immediately after the sample was cooled from 100°C. to room temperature;

b: photographed 3 hours after a;

c: photographed 5 hours after b;

d: photographed 13 hours after c.

tional to the volume of the inclusion itself. In figure 3b each elongated inclusion has segregated from itself on isometric inclusion. In the next figure 3c it can be observed that, during further differentiation of the elongated inclusions, their contained large gas bubbles became isolated in the relatively small inclusions. From this differentiation of the nonequilibriated inclusions at a temperature lower than that of the initial inclusions, emerged an assortment of inclusions having various ratios between the gaseous and the liquid phase (fig. 3d). In some inclusions of the latter type, ratios of volumes of phases correspond to formation temperatures of the inclusions (100°C. and room temperature), whereas in certain other inclusions (the two at the center in this case) there is a disproportionally large gas bubble.

It is entirely obvious that the experiment described discloses fully one of the principal causes of the appearance in minerals of secondary inclusions having diverse and anomalous ratios of the volumes of phases. Presence of such inclusions in a single healed crack indicates slow temperature decrease during change of shape and differentiation in those inclusions already closed but not yet equilibriated in form.

The phenomena of differentiation in inclusions and of uneven distribution of solid and gaseous phases, previously separated in them to a greater of lesser extent, can be encountered in almost all healed cracks. More frequently, they are found among the larger inclusions which change their shape more slowly. Small inclusions in a wedged-out part of the same crack usually have a constant ratio of the volumes of phases. Not infrequently, inclusions are found "frozen" in the stage preceding their complete separation; both parts of the inclusion, connected by an exceedingly thin channel, can have entirely different contents (see fig. 4).

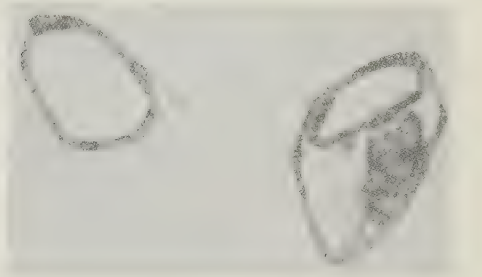

FIGURE 4. Topaz. Incomplete differentiation of an inclusion. The two parts, of entirely different content, are connected by a very thin channel; 62.5X.

In the performance of tests to determine the temperature of mineral formation based on homogenation temperature of inclusion contents at their heating , it is necessary to select carefully, among the total assemblage of inclusions in a healed crack, the particular inclusions to be observed. The inclusions chosen should not have ratios of phases that are too different from the ratios for a sufficiently large group of surrounding inclusions. Therefore, the surest method is to observe homogenation during simultaneous heating of a sufficiently great number of inclusions from the same healed crack, rather than of only one inclusion. If one limits oneself to measuring ratios of the volumes of phases at room temperature, this should be done, simultaneously, on a large number of adjacent inclusions as well. In this connection it must be noted that, even when inclusions do have diversified relations between phases for the reasons discussed previously, the average ratio still corresponds to that ratio which would exist in each inclusion had the processes of differentiation and transformation of shape been isometric. Thus, calculation of the sum total of the volumes of phases in many inclusions is the only practicable thermometry method in the case of the inclusions with varying ratios of the volumes of phases.

With use of the explosion method, (theoretical examination of this method has just begun), pres-

ence of healed cracks containing inclusions in the specimen tested should produce, apparently, corresponding thermal scatter of explosions toward very considerable temperature increase and toward temperature decrease.

In conclusion, it should be added that formation of the type of inclusion under consideration is possible not only in healed cracks but, in principle very conceivably as a result of the differentiation during change of shape of large primary inclusions in a matrix solution under declining temperature conditions.[3]

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[3]Reviewers comments; Probably an explanation for some wide range filling temperatures. However in most cases inclusions in one zone or plane tend to have identical filling temperatures. D.H.R.

ON THE MAGNESIUM-IRON MINERALS OF SCHISTS OF THE BUGITE COMPLEX[1]

by

V. P. Kostyuk

• translated by A. J. Shneiderov •

ABSTRACT

Schists of the Bugite complex of the Ukrainian massif contain the mineral assemblages: cordierite (Fe_{25})-garnet (Fe_{64})-quartz-sillimanite, cordierite (Fe_{25})-garnet (Fe_{64})-hypersthene (Fe_{41}), and garnet-hypersthene (Fe_{52}), with percentages of ferrous end members given by the Fe-subscripts. Chemical analyses and optical data are given for cordierite and garnet from the first assemblage, and of hypersthene from the second and third assemblages. These assemblages and the related ones are plotted on a Korzhinskiy-type ternary diagram of components Al_2O_3, FeO, and MgO, and with SiO_2 present in excess amounts. --F. Barker.

One of the principal methods now being used in the study of complexes of high-rank schists is paragenetic analysis, one of the tasks of which is to reveal the junctures between the fields [of stability] of individual rock-forming minerals.

From a study of certain definite mineral associations in metamorphic rocks, one using paragenetic analysis and constructing certain auxiliary graphs can follow all the regularities in the process of formation of minerals, and also foretell a number of other yet undiscovered mineral associations, or establish in advance the impossibility of occurrence of some such associations in nature.

A thorough interpretation of such paragenetic regularities in rocks can be found in numerous papers by D. S. Korzhinskiy and V. S. Sobolev [7].

The method of paragenetic analysis is very useful in studying associations with minerals that contain MgO and FeO or other oxides in isomorphous mixtures. The ratio between MgO and FeO is different in different associations (parageneses) but changes quite regularly.

An ability to detect these regularities allows for a purposeful investigation aiming at a determination of those points in the diagrams that have a decisive value for a practical study of various associations.

D. S. Korzhinskiy was successful in thoroughly developing the methods of paragenetic analysis and in preparing the graphs for most of the high-rank metamorphic crystalline rocks of eastern Siberia, after petrographic and physicochemical examination of their numerous types. In particular, a very important diagram was prepared for rocks of the Aldan complex that are rich in magnesium and iron, contain quartz, and are deficient in calcium [5]. Some of the points on the diagram were determined only approximately, those for cordierite and biotite in particular, since these minerals have not been analyzed chemically. It should be noted that the biotite, which also contains Mg and Fe^{2+} in the association considered, does not fit into the three-component diagram, yet a correlation between all the ferro-magnesian minerals of the association is of considerable interest.

From the study of crystalline rocks of the Ukrainian Massif, the so-called "Bugite complex" [2] in particular, it was found that in many cases a similarity with some types of rocks of the Aldan Massif, described in detail by D. S. Korzhinskiy, can be observed.

Using Korzhinskiy's method paragenetic analysis as the basis in our rock studies, we made thorough investigation of the chemical compositions of minerals along paragenetic junctures. Therefore, rocks were selected for chemical analysis which contain the greatest amounts of iron-magnesium minerals (cor-

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[1] Translated from O magnezialnozhelezistykh mineralakh iz kristallicheskikh slantsev Bugitovogo kompleksa: Mineralogicheskiy sbornik, Lvovskoe geologicheskoe obshchestvo, no. 5, p. 211-218, 1951.

dierite-bearing rocks, in particular) in an association; in some cases the rock was devoid of quartz but contained spinel, in others quartz was present. Moreover, the specimens for analysis were selected in such a way as to secure minimum amounts of iron in the dark-colour minerals (garnet, hypersthene, biotite) in the joined associations, while in other cases maximum amounts of iron in the same types of minerals were secured.

Thus, several specimens of garnet, hypersthene, biotite and cordierite were selected for chemical analysis. The analysis of cordierite is of special importance, since a determination of its chemical composition (the ratio of MgO to FeO, to be more accurate) from its refractive indices is hardly possible, because the change in the indices greatly depends on the content of alkalies, rather than on the content of iron. It was necessary to determine the indices of refraction of the dark color minerals by the immersion method, since we could not make a sufficient number of chemical analyses; and then, using the composition -- property graphs, determine the Fe:Mg ratios of pyroxene, biotite and a number of other minerals. Three hundred minerals found in various associations were investigated by this method.

The study of garnets was expecially difficult, because their indices of refraction are much higher than the range of usual immersion sets. And yet, the properties of garnet had to be thoroughly investigated, as it is one of the main minerals in the rocks of our area.

The crystalline rocks of the natural and man-made outcrops along the 55 to 60 km strike of these rocks (mostly in the Bug River valley) contain abundant garnet throughout much of the rock, with a few interruptions. Garnet frequently is the principal constituent in the rock. The amount of garnet-bearing inclusions is so great, especially along the right bank of the Bug River at the town of Strizhevka, in the outcrops at the city of Vinnitsa, from the town of Sabarovo to the town of Selishche, at Sutiski, Brailovo, and other locations, that N. I. Bezborodko gave this type of rock the name "vinnitsite", meaning garnet migmatite [2, 3].

The grain size of garnet varies greatly from one point to another. In some cases the crystals are isometrically rounded, with diameters from 0.8 to 1 cm, and less frequently as large as to 4-5 cm (at Strizhevka); in other cases garnet is present as medium or small crystals from 0. 5 to 1-2 mm or less in diameter. In such cases garnet is either evenly distributed in the mass of the rock, or, more often, is concentrated as separate linearly extended interlayers which, accompanied by aggregates of biotite lamellae, give the rock a distinctly striped appearance. Darkly colored stripes alternate with lighter ones of granitic composition.

There is also a case in which garnet is concentrated in the form of fairly large (as much as 3-5 cm in diameter) aggregations, some of which are spherical. In such aggregations the shapes of separate garnet crystals, usually very small and imbedded in a similarly shapeless quartz mass, cannot always be established, even on the surface of a freshly broken rock. These masses are found as isolated inclusions, elongated usually according to the general direction [strike of the rock], in pegmatite lodes that intersect the charnockite rocks common to this area.

The garnet in all the locations stated above, is pink-red regardless of grain size, although the intensity of coloring is not uniform: some of the garnet is light in color and transparent in thin section, whereas some is intensly colored in deep-red shades (Bordeau red), and is only slightly translucent.

Garnet is usually fresh. Mechanical disintegration has been observed at a few localities; very recent garnet sands have been found in quarry dumps. Here and there chemical weathering has completely removed the garnet from the rock, leaving a very porous matrix of unaltered feldspar and quartz. Garnet may be partially weathered to hydrous iron oxides, which fill the tiny cracks in the grains and make them turbid to opaque.

Large garnet crystals commonly contain many poikilitic inclusions of biotite, quartz, feldspar, and occasionally spinel.

Notwithstanding an apparent montony in external shape, coloring, and the average size of garnet grains, studies of its optical properties have revealed that the garnet composition varies in different specimens from that of pyrope-almandine containing 59 to 60 percent of FeO (its minimum content), almost to that of almandine containing 83 to 84 percent of FeO, with ferric oxide excluded. This variation in the garnet composition can be correlated with salic minerals on the one hand, and with dark-colored minerals on the other. In other words, the different parageneses the garnet takes part in are governed mostly by their correlation with other dark-color ed minerals and with the acidity of the rock. Besides garnet, biotite, hypersthene, and, less frequently hornblende are common dark-colored minerals frequently occurring in this particular complex. All of them contain Mg and Fe^{2+}, which are isomorphously interchangeable with one another.

Somewhat aside stands the other paragenesis of garnet and biotite, the one that contains a salic iron-magnesium mineral, cordierite. This association was found at three locations: in a quarry at the City of Vinnitsa proper, at Shkurnitsy town, and in a quarry of the town Bukhoniki.

Decomposition products of cordierite can also be found in thin sections from Gnivany quarries, but we could not find fresh cordierite there. In the deposits mentioned cordierite is concentrated in the medium and coarse-grained garnet migmatite (at Vinnitsa and Buchoniki), or in the fine-grained dark colored horblende-bearing interlayers in migmatite. The amount and size of cordierite grains were, in some cases, sufficient for separation from the rock as shapeless grains 3 to 4 mm in size, and also by the method of careful fractionation in heavy liquids (since its specific weight is 2.581, almost identical with that of quartz and plagioclase). Cordierite in a rock is invariably accompanied by tangled fibrous aggregates of acicular sillimanite which either borders grains of other minerals, or has grown within or through them. One of these minerals found in the quarry dumps often leads to discovery of the other mineral nearby.

In contrast to the accompanying light-colored quartz, macroscopic cordierite in the body of a rock appears rather dark, even pitch-black in color if its grain size is sufficiently large. Cordierite extracted from the rock has a slightly bluish tint in one of the crystallographic directions, and an orange tint in the other directions, and an orange tint in the other direction. In sections it often shows a regular or polysynthetic twinning. It can hardly be distinguished from acid plagioclase, especially if the bright orange pleochroic haloes characteristic of cordierite, and having their intense coloring in the X direction of the crystal, are absent.

Its optical characteristics are a positive optic angle of 77°, and the lowest, for cordierite generally, indices of refraction: γ = 1.542 to 1.548 and α = 1.532 to 1.537. The twin axis measured on the Fedorov table makes the following coordinates: 61 with γ, 29 with β, and 87 with α; that is, it fits the curve of Bowen's law for feldspars (021) and $(0\bar{2}1)$ if the mineral is compared with plagioclase. (Coordinates of the twin axis almost coincident with those mentioned above were obtained from measurements of numerous specimens of cordierite twins.)

We are not in a position to dwell upon the properties of other minerals, dark-colored ones included, since they, to some degree, are discussed in the papers of other authors [2,3,6].

We have given some descriptions of cordierite because, firstly, it is a peculiar salic iron-magnesium mineral and, secondly, it can be found in the rocks of our area either incidently, or only upon an examination of a large number of sections, since it is uncommon here. True, there is a thorough description of cordierite-bearing rocks of Zhezhelevo deposits by V. I. Luchitskiy [6], and indications of some cordierite at Brailovo by N. I. Bezborodko [3], but those sites are on the outskirts of the area described.

Since our garnets belong in the pyrope-almandine series, and lie above the range of our immersion liquids, we had to determine the indices with a goniometer.

We have made sufficiently accurate measurements of refraction of several dozen garnet specimens from different deposits and associations of the Bugite complex, from Strizhevke to Tyvrov: The ratio between MgO and FeO in them was determined with the aid of graphs. This ratio for the remainder of the dark colored minerals was determined from the chemical analyses available, or according to their indices of refraction in immersion liquids.

This permitted construction of a scheme of paragenetic relationships (when quartz is present) showing certain associations of minerals; for instance cordierite-sillimanite-garnet, cordierite-garnet-hypersthene, and garnet-hypersthene, thus confirming, and for our [particular] complex locating, the points in the graph given in D. S. Korzhinskiy's paper for the calcium-deficient mafic rocks.

Such a graph was constructed for the paragenetic analysis of crystalline schists of the Precambrian complex of the southern Baikal region by D. S. Korzhinskiy, and it exhibits an almost complete similarity with fundamental characteristics of our schists, except that olivine-bearing parageneses were not found in our area. Ferric oxide in these minerals was always excluded, and not re-calculated as ferrous oxide.

The hypersthene analyses of our collection were carried out at the laboratory of the Lvov Branch of the Academy of Sciences of the Ukrainian S. S. R. by S. I. Isvik, analyst. The analyses of cordierite and garnet were carried out at the chemical laboratory of the faculty of mineralogy of the Lvov University by A. S. Sivkova. Their data are given in Table 1.

The ratio $\left[\frac{FeO}{FeO + MgO} \cdot 100\right]$ for hypersthene is 41 percent when reevaluated into molecular quantities, and in round figures it is 45 percent when the entire iron content is included $\left[\frac{2Fe_2O_3}{Fe_2O_3 + FeO + MgO} \cdot 100 = 3.9\%\right]$. The refractive indices for γ and α are 1.718 and 1.704 respectively, and 2V = -60°. This analysis was used in the constuction of the graph in the paper by V. S. Sobolev [8].

Conversion of garnet (analysis II, Table 1) into molecular quantities gives a $\left[\frac{FeO}{FeO + MgO}\right]$ ratio of 0.64. The refractive index is 1.7920 and specific gravity 3.975, which,

TABLE 1. Analyses of hypersthenes, cordierites, and garnet

Composition	*I	**II	***III	****IV
SiO_2	50.00	39.36	49.48	56.04
TiO_2	0.30	1.64	0.81	—
Al_2O_3	3.05	23.26	1.40	31.30
Fe_2O_3	2.57	4.20	2.16	2.05
FeO	24.64	22.50	31.03	1.50
MgO	18.48	6.95	14.91	2.45
MnO	0.02	—	0.05	—
CaO	0.45	0.35	0.38	3.60
Na_2O	0.53	1.03	0.14	3.34
K_2O	0.42	0.29	0.24	0.08
H_2O	0.04	0.68	0.01	0.26
Other extraneous matter	—	—	—	0.52
TOTAL	100.50	100.26	100.60	100.14

*I Specimen 4/Ia, hypersthene in a paragenesis with cordierite and garnet.
**II Specimen 4/1, garnet in a paragenesis with cordierite and sillimanite.
***III Specimen 8/4, hypersthene in a paragenesis with garnet.
****IV Specimen 21/21, cordierite in a paragenesis with garnet and sillimanite.

according to Winchell's graph (4, p. 271), corresponds to a slightly different An-Al-Py ratio, namely, 8 percent for andradite, 62 percent for almandine, and 30 percent for pyrope. Deducting the iron oxide component, the amounts of almandine and pyrope become 67 percent and 33 percent respectively, if the third component is considered as andradite. When the CaO content is small (0.35 percent), the third component that effects the changes of garnet properties is probably khoharite, $Mg_3\ Fe_2\ (SiO_4)_3$. In these circumstances it must be taken into account when evaluating the ratio of the iron-magnesium component (ferric iron is excluded everywhere), which is 62:38. This agrees closely with the figure obtained in the analysis.

The $\frac{FeO}{FeO + MgO}$ ratio of the second hypersthene specimen (analysis III, Table 1) is 0.519 or 0.52 in round figures. γ = 1.736, α = 1.719, 2V = -57°. The refractive index of garnet from the same specimen in a paragenesis with iron-rich hypersthene, is 1.8279, and its specific gravity 4.13. The same graph (Winchell, p. 271) gives 12 percent "andradite", 80 percent almandine, and 8 percent pyrope. In analogy with the preceeding specimen, "andradite" is actually considered a khoharite component, the ratio of the iron component to that of magnesium is 80:20. When this ratio is corrected for CaO (by analogy with the analyzed specimen), the final $\frac{FeO}{FeO + MgO}$ ratio accepted for a determination of the point on the graph is 83:17. These data, and those about the composition of hypersthene determine the position of the tie line.

Finally, for cordierite (analysis IV, Table 1) the $\frac{FeO}{FeO + MgO}$ percentage is 25:75. The index of refraction is 1.542 for γ, 1.532 for α, and 2V = +72°. This corresponds to 15-16 percent content of the iron component in Winchell's graph [4, p. 459]. The noticeable disagreement is due, evidently, to an inaccuracy in the determination of cordierite content according to its index of refraction, which varies sharply under the influence of alkalies. The garnet from the same specimen has an index of refraction 1.7910, and a specific gravity 3.955. These figures are very close to the garnet from specimen 4/1 (analysis II, Table 1), therefore, using Winchell's graph (and excluding the "andradite" component) we obtain here 65:35 for the ratio of iron to magnesium.

The ratio would be 60:40 if the khoharite component ($Mg_3\ Fe_2\ [SiO_4]_3$) [Tr: the trivalency sign for iron in this formula is omitted.] were considered.

Thus, using in our case the two extreme series of parageneses: a) the least ferrous of cordierite-garnet-hypersthene (with sillimanite and without), and b) garnet-hypersthene having a high content of iron (biotite is excluded in both cases, since its composition cannot be represented on the graph), the iron-magnesium rocks of the Bugite complex were investigated, and we can plot definite positions of the points of these minerals on D. S. Korzhinskiy's graph, which for our rocks has the form as it appears in Figure 1.

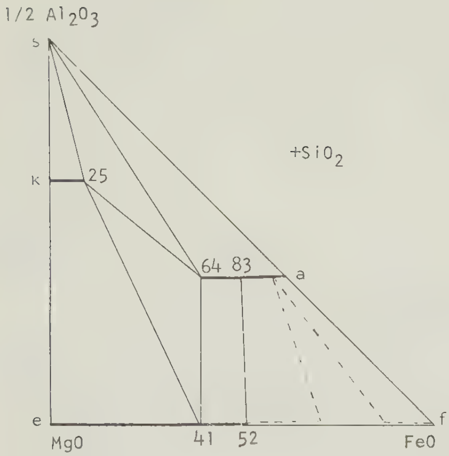

FIGURE 1. Graph of a four-component system $MgO - FeO - Al_2O_3 - SiO_2$ when SiO_2 is abundant, that is, a paragenesis with quartz.

s - sillimanite, k - cordierite, e - enstatite, f - fayalite, a - almandine

The entire research was carried out under the leadership of Prof. V. S. Sobolev, and in the laboratory determination of refractive indices of garnet by the goniometric method, the author consulted Dr. G. L. Piotrovskiy, to both of whom he expresses his gratitude.

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OLENEGORSK IRON-ORE CONCENTRATES[1]

by

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• *prepared by the United States Joint Publications Research Service*[2] •

ABSTRACT

This report describes the processing of iron-bearing quartzites mined at Olenegorsk and shipped to sintering plants in Poland. Projected annual productive capacity of concentrates is 1, 600, 000 tons. Explored reserves are estimated at 333, 000, 000 tons. --M. Russell.

Last May the Bierut steel plant received from the U.S.S.R. the first shipment of a new, and hitherto unknown in Poland, grade of iron ore concentrates from Olenegorsk of the Kola Peninsula. These concentrates, which will complement the ore deliveries from Krivoi Rog, are being exported by the U.S.S.R. for the first time, and Poland is their sole foreign consumer.

The importing of these concentrates is intended to improve the operating conditions of sintering plants and thus to improve the balance sheet of slack ores for sintering. In recent years this balance sheet indicated a disproportion between the increase in the sintering capacity of the metallurgy of iron and the quantity of the available slack ores of proper quality in Poland. In the last six years the output of sintered clinkers had risen from 883, 300 tons in 1952 to 4,450,000 tons in 1958, i.e., fivefold, while the consumption of ores and other ferriferous materials in sintering plants had increased approximately to the same extent.

Whereas in 1953, for every 100 tons of lump ore, only 24 tons of slack ores processed into clinker in sintering plants were consumed in blast furnaces, in 1958 this ratio changed to 118 tons of clinker for every 100 tons of lump ore. In this connection, the Polish ore mining industry in 1958 will supply the steel plants with only two and a half times as much slack ore as in 1953.

The above proportions indicate the great importance of the adequate supply of charge for sintering plants and, from this standpoint, a smattering of information on this new and hitherto unknown grade of concentrates in Poland will surely interest the reader.

Far in the North, 180 kilometers beyond the Polar circle, on a geographical latitude corresponding to Greenland and the northern shores of Alaska, in the locality of Olenegorsk situated on the railroad line bisecting the Kola Peninsula and connecting Murmansk to the rest of the U.S.S.R., the first part of a large Kombinat processing the local iron-poor quartzite ores has been operating for the last three years. The projected productive capacity of that first part amounts to 1, 600, 000 tons of concentrate annually, and of the kombinat as a whole, 2, 800, 00 tons, which in terms of iron corresponds to three times as much as the quantities received annually by Polish steel plants from all Polish ore mines as a whole.

The raw material base of the kombinat, which was opened in November of 1954, is constituted by a deposit of ferriferous quartzites of metamorphic origin (one of the three discovered and explored on the Kola Peninsula in recent years), outcropping in the Olenegorsk region. This deposit runs from north-east to north-west, gradually submerging under the biotitic gneiss formations constituting its "mother" rock. Exploitation is conducted on sites where the ore-bearing strata crop up to the surface (and even form elevations and hills) and where they are overlain by only a thin (several meters thick) other stratum.

The extraction is conducted by the strip-mining method, which is applied with increasing frequency in Soviet mining; compared with 1955, the scope of strip mining work in 1960 will increase two and a half times in the U.S.S.R., and reach the level of one and a half billion cubic meters. Already at the present time 55 percent of all iron ores, half of the nonferrous metal ores and up to 70 percent of all nonmetalliferous minerals (inclusive of the whole of construction materials) are extracted by precisely this method [1].

Such expansion of surface or strip mining is justified by the advantages of this system compared with underground mining; it permits the application of large and high-efficiency mechanized equipment multiplying labor productivity at several times lower financial outlays, it reduces considerably the losses in mineral left in the ground, it makes possible work in healthier and safer conditions than under the ground, and so forth.

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[1] Translated from Wiadomosci Hutnicze [Metallurgical News], Katowice, Poland, v. 14, no.6, p. 182-185, June 1958.

[2] JPRS/NY-L-425,

These circumstances justify the expediency of strip mining even at a considerable thickness of the overlying stratum, reaching several score meters and more [1]. In Olenegorsk the conditions in this regard are, as noted before, much more favorable.

From the mineralogical standpoint, the Olenegorsk ore is constituted mostly by magnetites, and, to a smaller extent, hematite, as well as limonite, found in very limited quantities, chiefly in the surface stra

The project postulates from the kombinat assumed the quantitative ratio of magnetite to hematite at 3:1. Actually it is different at present, because the major part of the extracted ore consists of hematite rather than magnetite, as is also indicated by the analysis later on. Furthermore, this ratio changes with the progress of extraction and the extension of its scope to new ore masses.

The explored resources of the deposit, down to a depth of 200 meters, were estimated at 333 million tons. Drillings deeper than 200 meters have not yet been executed. The ore is combined with quartz, and the diameter of the magnetite and hematite grains varies from 0. 03 to 0. 8 millimeters.

The natural ore contains only 30 to 32 percent of Fe at 42 to 46 percent of SiO_2. The extract from the laboratory notebook of daily sample analyses for 16 February 1958 shows the following values:

	Percent
Fe (Total)	32. 2
FeO	4. 6
Fe_3O_4	14. 9
Fe_2O_3	30. 6
FeSi	1. 1
SiO_2	49. 05
Al_2O_3	1. 65
CaO	0. 83
MgO	0. 65
P	0. 022
S	0. 04

Noteworthy is the very low content of phosphorous and other impurities, typical for the deposit as a whole.

The region comprised by strip-mining exploitation is at present 3 kilometers long and about 2. 5 kilometers wide. Six shovels with a scooping capacity of 3 cubic meters each are operated on that area. These shovels come from the Sverdlovsk "Uralmashzavod" Machine Plant, and the productive capacity of each amounts to 60, 000 to 70, 000 tons of natural ore monthly. It may be noted that these shovels are not the "last word" in Soviet or world engineering in this field. As stated by the Gorniy Zhurnal, as early as last year some other iron-ore surface mines had already been using EKG-8 shovels with scooping capacity of 8 cubic meters, a weight of 320 tons, a shoveling depth of 12. 2 meters in a radius of 17 meters, and a maximum height of unloading amounting to 8. 4 meters; the shovels used in the new large ore basin in Kazakhstan have a scooping capacity of 14 cubic meters.

The simultaneous blasting of a series of charges placed on a sector measuring 100 to 150 meters yields 200, 000 to 400, 000 tons of extraction. The blasted ore is loaded onto 60-ton automatic unloading freight cars and hauled by electric traction to the dressing plant. The loading time for a five-car freight train, inclusive of freight car manipulation (switching, hauling freight car under shovel, etc.) lasts 20 to 25 minutes. The distance between the strip-mined working and the plant is several kilometers. Work on the strip mine area is continued regardless of temperature and weather, and in the event of a strong frost and the resulting drop in labor productivity the work quota for which the miners' earnings are computed are correspondingly lowered.

The ore processing plant was project- designed by the Leningrad "Mekhanobor" Institute on the principle of combined magnetic-gravitating dressing. It differs, among others, from the "Yugok" Krivoi Rog kombinat, better known to Polish metallurgists, in that it processes a poorer ore (the starting material for "Yugok" contains 36 to 40 percent of Fe) and that it uses the gravitating method in addition to magnetic separation for dressing the ore, and applies a different and more modern method for dehumidifying the concentrate without using the vacuum filters which "Yugok" employs in the quantity of several tens, and in that the final product is a concentrate whereas the "Yugok's" final product is a clinker sintered from a mixture of Krivoi Rog and concentrate ore.

The natural ore furnished by the mine in Olenegorsk is subjected to a three-stage crushing: preliminary crushing, to 250 millimeters, is conducted in a jaw-type 2,100 x 1,500 millimeter breaker with a capacity of 700 to 800 tons an hour. In the "Yugok" kombinat this operation is conducted in a cone-type crusher with a capacity of 1,500 meters an hour. After crushing to 250 millimeters, the ore in Olenegorsk is processed through a 2,100 millimeter cone-type crusher where it is granulated to 60 or 70 millimeters, and thereupon it undergoes the third stage of crushing-granulation to 25 millimeters on short-cone crushers with a capacity of 200 to 250 tons an hour. There are four such crushers, including one held in reserve.

The ore crushed in this way is then processed through (three) 2,700 - 3, 600-millimeter rod mills in which it groun down to 0. 2 millimeters. The resulting slack is conveyed to a spiral classifier with a cross-section of 2 millimeters. The result of this classification-fraction with a diameter of up to 0. 3 millimeters is conveyed directly to wet magnetic separation,

while the coarser-sized fraction is additionally processed through 2, 700 - 3,600 ball mills where it is ground to a maximum of 0.5 millimeters and then also conveyed to magnetic separation.

In the separators the charge is divided into concentrate and semi-finished product. The latter is subjected to dehydration and dressing and then combined with the concentrate isolated in the preceding stages of the technological process. The so-called khvosty or weeds (i. e., unusable refuse) which go to dumps - still contain up to 10% of Fe.

The typical chemical composition of the finished concentrate is as follows:

	Percent
Fe (Total)	60. 8
FeO	13. 1
Fe_3O_4	42. 0
Fe_2O_3	43. 0
FeSi	0. 5
SiO_2	13. 2
Al_2O_3	0. 23
CaO	0. 60
MgO	0. 28
P	0. 017
S	0. 02

The moisture content of the finished product, i. e., the concentrate, is about 7 or 8 percent. In the period from 15 October to 15 April the concentrate is additionally subjected to drying in five rotary furnaces measuring 2, 800 x 14,000 millimeters and having a capacity of 38 tons an hour each. This operation is intended to counteract the freezing of wet concentrates during transport to consignees.

The entire output of the Olenegorsk kombinat is, aside from the part earmarked for export to Poland, sent to the steel plant in Cherepovets (one of the steels plants farthest to the north - between Leningrad and Vologda). Considering that the concentrate dried in the rotary furnaces is a very loose and dusty material, it is transported in especially adapted freight cars in which the hatches and other openings and fissures are welded shut. The unloading of such freight cars in the Cherepovets steel plant is conducted with a dumping trestle. It should be noted that the distance between the kombinat and the steel plant amounts to as much as one and a half thousand kilometers (the distance between the Krivoi Rog basin and the Silesian steel plants is about 1, 400 kilometers). One and a half thousand freight cars are assigned to ore transport and the roundtrip time of a freight car lasts 7 days.

The concentrate received from Olenegorsk is (after lumping up in the sintering department) the basic charge of the blast furnaces of the Cherepovets steel plant. As indicated by the evaluation of the 1957 performance of Soviet metallurgical industry, published in the January issue of Stal', the steel plant in Cherepovets has advanced to the leading rank among all other Soviet steel plants, outpacing even such distinguished steel plants as the one in Magnitogorsk. The volumetric efficiency factor (KIPO - koeffitsient ispol'zovaniya poleznogo ob'yema) of the blast furnaces in the Cherepovets plant amounted to 0. 72 in 1957 (the overall factor for all blast furnaces in the U. S. S. R. amounted to 0. 79 in that year). The high (chemical) basicity of the clinker sintered in Cherepovets from the Olenegorsk concentrates makes it possible to eliminate limestone from the blast-furnace charge for the production of pig-iron for open hearth furnaces.

Beginning with this year Polish steel plants will, as noted before, become another customer of the Olenegorsk kombinat while the resulting reduction in the deliveries for the Cherepovets steel plant will be compensated by pyrite sinters.

The concentrates will be transported to Poland by sea via Murmansk, a non-icing harbor, situated a little over 100 kilometers from the kombinat. For technical reasons, and to avoid losses of concentrate en route, the ore consignments for export to Poland will not be additionally dried in furnaces, owing to the lack of a greight car dumping trestle in the harbor (which necessitates the hauling thereto of ore in ordinary freight cars with non-welded hatches), and thus their moisture content of ore is determined individually for every consign ment and considered in the accounting.

Considering the presence of about 6 percent of H_2O in the ore, the period of concentrate transportation to Poland will be limited to the period from May to October only, as in that period the ambient temperature will not freeze the ore in freight cars en route from Olenegorsk to Murmansk. This is because the mean temperature drops to -10°C as early as October.

The shipments of the finished product of the Olenegorsk kombinat are conducted in both summer and winter through the warehouse only - which of course causes the standardization of concentrate and improves the uniformity of ore. The storehouse consists of a rooved hangar, and the freight cars are loaded by means of an overhead crane with a scoop having a capacity of 20 tons. The piling up weight of the concentrate is 2. 65 tons per cubic meter, and its specific weight is 4. 6 grams per cubic centrimeter.

The granulation of the finished product, according to screen analysis, and the shares of the individual fractions and their iron content are presented in Table 1.

The share of the smallest fraction, passing through a screen with 0. 1 millimeter holes, sometimes reaches 20 percent.

TABLE 1. Granulation of the finished product

Fraction, in millimeters	Shares of individual fractions in percent	Iron content in fraction, in percent
Over 1.7	1.2	46.2
1.2 - 1.7	3.0	50.2
0.6 - 1.2	12.4	55.3
0.4 - 0.6	14.2	57.1
0.21 -0.4	15.0	58.3
0.1 - 0.21	47.1	62.3
Below 0.1	7.1	60.0

Table 2 compares the qualities of the Olenegorsk concentrates with those of the concentrates imported from the Scandinavian countries (average analyses).

The economic expediency of importing concentrates from the Kola Peninsula to Poland is an indubitable one. The distance from the Murmansk harbor to Polish harbors is somewhat over 3,000 kilometers. This is about 30 percent further than the distance from the northern Norwegian harbors from which Poland receives a part of the deliveries of Scandinavian ores. The maritime freight rates on the Murmansk-Szczecin route are 10-15 percent higher than the rates on the route from the northern Norwegian harbors to Szczecin. The cost of transporting the Olenegorsk concentrates to a Polish port equal 20 - 25 percent of the price of the ore itself. The distance from Brazilian to Polish ports is 11,000 kilometers, from the African ports it is not much less, and from the Chinese ones it is as much as 19,000 kilometers. Thus, in comparison, the route to be traversed by the Olenegorsk concentrates to Polish ports is not too long. For the iron ores imported from India or Brazil the transport costs equal 60-80 percent of the price of the ore itself, while at still greater distances of ore sources these maritime transport costs reach or even exceed the price of the ore.

TABLE 2. Comparison of Olenegorsk and Scandivanian concentrates

Component	Olenegorsk concentrate	Finnish Otanmaki concentrate	Norwegian Fosdalen concentrate	Norwegian Svdvaranger concentrate	Swedish Gellivare A-30 concentrate
	%	%	%	%	%
Fe	59.5	65.0-68.0	66.0	64.0	70.0
Mn	0.08	0.1	0.23	0.1	0.08
SiO_2	14.5	0.5-1.3	5.3	8.8	2.12
Al_2O_3	0.16	0.5-1.8	00.5	0.2	0.1
CaO	1.16	0.1	0.9	0.58	0.13
MgO	0.92	0.9	0.72	0.69	0.10
P	0.02	0.002	0.025	0.01	0.02
S	0.03	0.1-0.2	0.7	0.027	0.02
TiO_2	0.11	2.5			
V_2O_3	5.0-7.0	0.86			
H_2O		4.0-9.0	7.0	7.0	6.3

As indicated by screen analysis the granular composition of the Olenegorsk concentrates is more favorable than that of the Finnish and the Norwegian ones. It is not as good as that of the Swedish Gellivare A-30 concentrates, however, only limited quantities of the latter can be available for Poland.

While only a small part of the Olenegorsk concentrates is taken up by fractions below 0.1 only 25 percent of the Finnish concentrates comprises fractions higher than 0.1, with the other 75 percent being taken up by very fine and dusty slack. As for the Fosdalen concentrates, only 23 percent of their fractions is above 0.2 millimeters, while the remainder is a powdery dust much less suitable for sintering.

As can be inferred from the above, the higher iron content of the Scandinavian concentrates is coupled with a higher degree of powderiness, which makes them less suitable for sintering compared with the Olenegorsk concentrates.

Considering the universal shortage of rich iron ores, and especially of rich iron ore concentrates, for which the purchasing possibilities are becoming smaller, and in the light of the above cited technical and economic data pertaining to the Olenegorsk concentrates, it may be expected that the metallurgists using these concentrates will appraise their deliveries positively.

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ON THE PROBLEM OF THE AGE OF THE GABBRO-PERIDOTITE FORMATION IN THE URALS[1]

by

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ABSTRACT

In this paper it is confirmed by means of study of the magnetic properties that the pebbles of igneous rock from the Eifelian conglomerates of the Pri-Polar Urals are derived from the platinum-bearing gabbro-peridotite formation and its age is established as Caledonian. In the author's opinion mass measurement of magnetic properties and statistical analysis of the results permits the use of comparison of the value of the vector of remanent magnetization as a supplementary criterion for age correlation of igneous rocks.

In using a pre-Eifelian age for the platinum-bearing gabbro-peridotite formation (together with the diorites and plagiogranites) of the central and northern Urals, numerous indirect considerations were expressed by N. K. Vysotsky, Ye. P. Moldavantsev, V. M. Sergievsky, B. M. Romanov, and several others. Investigations in subsequent years, particularly the works of S. N. Volkov [1] and V. P. Loginov [6], confirm these considerations.

S. N. Volkov's data for the Bolshaya Lyulya and Bolshaya Sosva rivers show that basal polymictic conglomerates at the base of the Middle Devonian lie unconformably on paleontologically dated Coblenzian and older sediments. In turn the conglomerates here are overlain by paleontologically identified Eifelian limestones. The Coblenzian and Eifelian fauna from S. N. Volkov's collection were identified by D. V. Nalivkin. In the pebbles of these conglomerates, in addition to sedimentary and volcanic rocks, there also were intrusive rocks: quartz diorites, plagiogranites, plagiogranite-aplites, garnet-epidote skarns, and also fragments of magnetite ore. According to V. M. Sergievsky and N. A. Sirin, based on petrographic and geologic studies, the complex of pebbles of intrusive and contact-metamorphic rocks in the conglomerates in question could be derived only from the intrusions of the platinum-bearing gabbro-peridotite formation. In connection with doubts expressed in this respect ([10] and others) it would be interesting to confirm the provenance of the pebbles of the Lyulinsk and Sosvinsk conglomerates from the rocks of the platinum-bearing gabbro-peridotite formation by another method, the more so because it is hardly possible to solve this question problem by purely geologic methods, particularly by petrographic study and comparison, for according to A. N. Zavarit- [2] there is no essential difference between igneous rocks of different age.

The Eifelian conglomerates from S. N. Volkov's collection have been at our disposal and we have had the opportunity to study the pebbles petrographically, investigate their magnetic properties, and compare them with the magnetic properties of similar rocks from the gabbro-peridotite formation.

Below is a description of thin sections of these rocks (by Yu. E. Moldavantsev) and features of their magnetic properties (table 1).

Quartz gabbro-diabase (?) (amphibolized and carbonatized) (Sample 651-1). The rock consists mainly of plagioclase, a basic andesine to acid labradorite (in the central part of the grains). The dark minerals are represented by monoclinic pyroxene, replaced by common green hornblende to a considerable degree. The latter, in turn, is replaced by carbonate and to a lesser degree of chlorite. Biotite is present in small amounts. Quartz, in the amount of from 5 to 7 percent, occupies the interstices between grains of plagioclase and dark minerals. Magnetite is present in notable amounts. Apatite is encountered.

The texture of the rock is determined by the rather strong idiomorphism of the plagioclase with respect to the dark minerals and in places approaches both hypidiomorphic and ophitic.

Porphyritic plagiogranite (Sample 651-4). Plagioclase constitutes the essential mass of the rock and consists of oligoclase, partly serpentinized and saussuritized. Potassium feldspar is present in small amounts, sometimes forming narrow rims around grains of plagioclase or grading into micropegmatitic intergrowths with quartz. The latter is present in the amount of about 25 to 30 percent.

The hornblende is the common green variety. Rather frequently it occurs in irregular forms and is replaced by a fine-grained felted aggregate of hornblende. Accessory minerals are

[1] Translated from K voprosu o vozraste gabbro-peridotitovoy formatsii na Urale: Akademiya Nauk SSSR Izvestiya, Seriya Geologicheskaya, 1956, no. 9, p. 44-50.

represented by magnetite and apatite.

The texture of the rock is hypidiomorphic. Plagioclase is found in the phenocrysts.

Plagiogranite (Sample 651-3) is much like sample 651-4. It differs in its larger hornblende content and somewhat smaller quartz and potassium feldspar content.

Chlorite and epidote are present.

Amygdaloidal spilite or spilitic porphyry (Sample 651-5). The rock consists of microlites of albitized plagioclase with interstitial actinolite amphibole and small amounts of chlorite. Magnetite is also present. The amygdules are filled with actinolite.

The phenocrysts are pseudomorphs of fibrous amphibole (uralite) after pyroxene (?).

The texture is apointersertal and in places trachytoid, depending on the orientation of the plagioclase microlites.

dealing with the pebbles from a conglomerate the magnetic characteristics obtained may be regarded as a selection from an infinite "general" totality, representative of a certain complex of igneous rocks as yet unknown to us; the selection is fully representative because it is absolutely random.

Table 2 gives the magnetic characteristics of some rocks attributed to the gabbro-peridotite formation, from the collection of B. Ya. Osadchev and L. A. Polunina, collected by them in the Pri-Polar Urals from outcrops of Eifelian conglomerates. The magnetization of the rocks was measured in the astatic system as in the first case.[2]

Comparison of Tables 1 and 2 shows that the magnetic susceptibility (χ) and remanent magnetization (J_r) are characterized by a certain order of magnitude and that the ratios of remanent magnetization (J_r) to induced magnetization (J_i) correspond. As will be shown below, such correspondence of the magnetic characteristics and particularly of the ratio

TABLE 1. Magnetic properties of rocks of conglomerate pebbles

Number	Sample Number	Name of rock	Magnetic susceptibility χ x 10^6 cgs	Remanent magnetization J_r* x 10^6 cgs	J_r/J_i
1	651-3	Plagiogranite	3200) av. 2959	470) av. 465	0.29) av. 0.32
2	651-4	Plagiogranite	2700)	460)	0.34)
3	651-5	Spilite	2900) av. 3250	350) av. 445	0.24) av. 0.27
4	651-2	Spilite	3600)	540)	0.30)
5	651-1	Gabbrodiabase	6900	800	0.23

* J_i--induced magnetization.

TABLE 2. Magnetic properties of rocks of gabbro-peridotite formation

Number	Name of rock	Sample Number	Average χ x 10^6 cgs	Average J_r x 10^6 cgs	J_r/J_i
1	Plagiogranite	10	3000	403	0.30
2	Spilite	16	2100	440	0.29
3	Diabase	31	2000	330	0.33
4	Gabbro	9	3650	560	0.31

Spilite or spilitic porphyry (strongly altered) (Sample 651-2). The interstices between microlites of plagioclase are filled with chlorite. Quartz, carbonate, and ore minerals are present. Occasional phenocrysts of plagioclase are replaced by carbonate. The texture is apointersertal.

Table 1 presents the results of measurements of the magnetic properties of the rocks of the conglomerate pebbles.

The measures were made by the author by means of an astatic magnetometer in an experimental magnetic station.

Inasmuch as in this case (table 1) we are

J_r/J_i permits us to confirm that the complex

[2]In measuring the magnetization of the rocks we proceeded from the thesis expressed early by Logachev [4, 5] concerning the possibility of obtaining reliable measurements (error not more than 10 percent) of the magnetic susceptibility and remanent magnetization in tests of samples of arbitrary form, that only if simple elementary forms of samples are treated can there be achieved sufficient multiplicity of determinations of the magnetic properties necessary to obtain correct conclusions concerning the magnetization of the rock, based for the purpose on an adequately supported average value. To secure more accurate data we endeavored as far as possible to give the samples as isometric form, particularly where the rock type was represented by less than 10 samples.

of igneous rocks in the pebbles of the Eifelian conglomerates belongs to the gabbro-peridotite formation, and that the formation itself is Caledonian in age.

The fact is that the remanent magnetization of igneous rocks is thermomagnetization which is closely linked with their geologic history.

The theory explaining the origin of remanent magnetization in rocks at the time of their formation and cooling in a magnetic field is called the theory of thermoremanence. For earliest publication of this theory we are indebted to the works of Melloni, Thellier, and Koenigsberger. Later, in 1938, it was formulated definitively [11]. Experimental proof of the theory of thermoremanence was obtained in the investigations of T. N. Roze, M. A. Grabovsky, Nagata, Hospers, Roche, and others.

At the present time the theory of thermoremanence is accepted by an overwhelming majority of scientists.

According to this theory, the magnetic field acting on a rock at the time of its formation is fixed in it in the form of the remanent magnetization, the direction of which coincides with the direction of the geomagnetic field of the epoch of genesis of the rock.

If the rock has not been heated and later cooled, the direction of the remanent magnetization is unchanged, and its intensity is a function of time and can serve as an indication of the age of the rock. Koenigsberger called attention to the fact that whereas the ratio of remanent to induced magnetization (I_r/I_i) in young lavas is very large and in Recent lavas is often more than 50, in old (Carboniferous and older) rocks this ratio is comparatively small, and the remanent magnetization of the old rocks is only a fraction of a formerly stronger magnetization that has been partially lost in the course of their geologic history.

Notwithstanding such important conclusions following from the theory of thermoremanence, we in this country [U. S. S. R.] were not interested in studies of the remanent magnetization of igneous rocks formed in different geologic epochs, i. e., in studies of paleomagnetism. In 1947, and then only to the extent of raising questions, there appeared V. I. Pogov's interesting paper on paleomagnetic investigations for correlating igneous formations according to the direction of remanent magnetization. There has been a little work on the magnetic properties of sedimentary rocks for correlation purposes. Among these can be named the works of A. G. Kalashnikov (1941) and A. N. Khramov (1955).

Abroad, since Thellier and Koenigsberger, a number of scientists have concerned themselves with problems of paleomagnetism: Hospers, Runcorn, Bruchshaw, Asami, Graham, and others. The works of Chatterton and Manley on the dependence of thermoremanent magnetization on the rate of cooling of the rocks have been of great significance for the study of paleomagnetism. Foreign scientists are investigating remanent magnetization not so much for the purpose of age correlation as for studying the direction of the earth's magnetic field in the geologic past, and also in relation to the problem of reverse magnetization. They are working chiefly with the direction, but not with the magnitude, of the vector of remanent magnetization, and the object of their investigations is young (Eocene and younger) magnetically stable lavas and horizontal volcanic layers.

Recently we have carried on a comparative study of the magnetic properties of rocks from the Urals and other regions. The magnetic properties of the rocks were studied in relation to their age, mineralogic and petrographic composition, form of intrusive body and its structure, and also in relation to the problems of reverse magnetization.

The data of these investigations convince us all the more of the fact that the remanent magnetization (its absolute magnitude, ratio to induced magnetization, and in some cases direction) not only enables us to distinguish very old from very young rocks, but also possibly provides a method of finer correlations (at least, within the limits of error) not only of young lavas and horizontal volcanic layers, but also of other extrusive and intrusive formations of different ages.

For confirmation of the conclusions expressed above on the contemporaneity of the rocks of the gabbro-peridotite formation and the conglomerate pebbles, based on the similarity of their magnetic properties, we should show that rocks having similar petrochemical characteristics but differing in age have different magnetic properties. For this we offer a comparison of two types of rocks of different age, diabases and granites (tables 3 and 4) and then we compare igneous complexes of different forms and different ages (table 5). Table 3 gives diabases of various ages. Of these, the first three groups are related to the upper Caledonian epoch of folding, the fourth to the Hercynian, and the fifth group are the Cenotype diabases. The Cenotype diabases are the youngest of those listed in Table 3; there is some basis for assuming that they are upper

TABLE 3. Magnetic properties of diabases of various ages

Number	Name of rock	Number of samples	Place collected	Age	Average χ x 10^6 cgs	Average J_r x 10^6 cgs	J_r/J_i
1	Diabase	31	Pri-Polar Urals (Lapp border)	Pre-Eifelian S_2ld?	2,000	330	0.33
2	Diabase	2	Polar Urals	Pre-Devonian	2,600	400	0.31
3	Diabase	7	Pri-Polar Urals (Nyaksimvolsk region)	Givetian D_2^2	3,200	630	0.39
4	Diabase	5	Pri-Polar Urals (Nyaksimvolsk region)	Lower Carboniferous	1,500	1,600	2.10
5	Cenotype diabase	2	Pri-Polar Urals (Nyaksimvolsk region)	post-Lower Carboniferous	810	8,500	21.00

Paleozoic or lower Mesozoic in age (B. Ya. Osadchev and S. N. Volkov)[3]

Table 4 gives granites of various ages. The first two groups belong to the early Caledonian epoch of folding, the third to the Upper Devonian, the fourth to the Hercynian.

TABLE 4. Magnetic properties of granites of various ages

Number	Name of rock	Number of samples	Place collected	Age	Average χ x 10^6 cgs	Average J_r x 10^6 cgs	J_r/J_i
1	Granite	6	Polar Urals	Pre-Lower Silurian	430	50	0.23
2	Granite	2	Pri-Polar Urals	Pre-Lower Silurian	670	80	0.24
3	Granite	14	Polar Urals	Lower Silurian S_1?	1,000	190	2.10
4	Granite	55	Altay*	Upper Carboniferous and Lower Permian	1,350	1,440	2.13

* In this case, as in the following, the data on the magnetic properties of the rocks from the Altay are quoted from the published work of Liogenky.

Table 5 shows the values of magnetic properties of three igneous complexes, represented by a large number of samples. These complexes include rocks from acid to ultrabasic, both intrusive and extrusive. Among the intrusive rocks in the first complex basic (gabbro) and ultrabasic (peridotites) predominate, in the second basic (gabbro), in the third acid (granites). The first two complexes are mainly Caledonian (Polar and Pri-Polar Urals), the third is Hercynian (Rudny Altay) [9]. Fortunately the Hercynian age of the third is confirmed by a radioactive age determination (230-255 million years).

TABLE 5. Magnetic properties of igneous complexes

Number	Name of region	Number of samples	Epoch of folding	χ x 10^6 cgs	J_r x 10^6 cgs	J_r/J_i
1	Polar Urals	217	Early Caledonian	4,200	820) av. 525	0.38) av. 0.42
2	Pri-Polar Urals	500	Late Caledonian	1,000	230)	0.46)
3	Altay	163	Hercynian	600	710	2.38

The magnetic properties of the complexes on the basis of the values of the absolute maxim of the variational curves plotted for the igneous rocks of each complex as a whole.

In spite of the comparitively small number of determinations in the first two cases, the following conclusions can be drawn from the data in tables 3 through 5.

1. Rocks that are similar petrographically

[3] In T.N. Roze's [8] experiments for the purpose of confirming the theory of thermoremanence, there figured a sample of diabase from Karelia, apparently belonging to the Proterozoic. Remanent magnetization was lacking in this diabase and reappeared only after artificial thermomagnetization of the sample. This experiment also serves as evidence that the Karelian diabase could have had noticeable remanent magnetization and in all probability did have it, but lost it in the course of time (considering its age).

but of different ages have different magnetic properties; the magnetic characteristics of rocks, sometimes even of different types, but of similar age, are similar.

2. The value of the ratio of remanent to induced magnetization, and in the case of petrographically similar rocks, also the absolute value of remanent magnetization, varies inversely with the age of the rock (and vice versa).

3. The order of magnitude of the ratio of remanent to induced magnetization is constant not only for rocks of similar age in limited regions, but is repeated in the Polar Urals, the Pri-Polar Urals, and the Altay, and apparently is of very broad significance.

4. A difference in the basicity of rocks, likewise in ferromagnesian mineral content (as accessories) brings about a difference in the absolute values mainly of magnetic susceptibility, and partly of remanent magnetization, that does not affect, or hardly affects, the value of the ratio (J_r/J_i) which depends chiefly on the age of the rock.

By confirming in this manner the derivative of the igneous pebbles in the Eifelian conglomerates from the gabbro-peridotite formation, we therefore establish a very satisfactory upper age limit for the latter. The coincidence of the J_r/J_i ratios for the rocks in Tables 1 and 2 with the J_r/J_i ratios characteristic of the rocks of Caledonian age in Tables 3 and 5 supports our correlations of the gabbro-peridotite formation with the Caledonian epoch of folding.

Rocks and their magnetic properties are extremely complicated objects of study inasmuch as very diverse factors act together in them.

Thus, the remanent magnetization of a rock depends on its temperature of formation, rate of cooling, position within an intrusive or extrusive body, depth, subsequent history of development of the segment of the earth's crust in which it occurs, and so forth.

The effect of all these factors on the remanent magnetization should be thoroughly studied and taken into account as far as possible.

To take some of these factors into account presumably is not possible, consequently even in the case of measurement of the magnetic properties of the very same rocks, different results may be obtained because of the conditions of their magnetic stability; but in no event does this mean that the magnetic method of age correlation of rocks lacks possibilities.

The relationship between the age of rocks and remanent magnetization is not always functional; more often it is stochastic, but it does obtain. Only, by virtue of the above discussion, the necessary condition for the purposes of paleomagnetism and age correlation appears to be multiplicity of determinations and their careful statistical analysis.

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STAGES IN THE DEVELOPMENT OF BRACHIOPODS AS ONE OF THE CRITERIA FOR ESTABLISHING STRATIGRAPHIC BOUNDARIES IN THE CARBONIFEROUS[1]

by

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ABSTRACT

The basic stages in the development of brachiopods corresponding to the boundaries of divisions and Stages of the Carboniferous are briefly examined. Data on the stratigraphic and geographic distribution of the more characteristic genera and species are analyzed. The author concludes that, in the brachiopod fauna of the Carboniferous, which form a single, mutually related whole, two main boundaries occur. This necessitates a three-fold division of the Carboniferous. -- Auth.

The Carboniferous as a whole corresponds to one of the basic stages in brachiopod development during the Paleozoic.[2] During early Carboniferous time, brachiopod genera typical of this System appeared; most important are listed in Table 1. The majority of these genera continued through the Carboniferous and disappeared at the end of the System. One of the important Carboniferous genera, Spirifer, s. str., characterizes the lower Carboniferous and continues into the lower parts of the middle Carboniferous (Spirifer bisulcatus Sow. and S. striatus Sow.). The genera Neospirifer and Choristites are directly related to this genus; the first of these appears in the middle Carboniferous and the second in the upper part of the lower Carboniferous (in Namurian R [B?]) and in some regions (for instance, in the Karnian Alps) continues to the Permian [44]. However, most Permian forms similar to Choristites in external appearance need further special study of internal structure to determine their identity.

[1]Translated from Etapy razvitiya brakhiopod kak odin iz kriteriyev provedeniya stratigraficheskikh granits v karbone: Moskovskogo Obshshestva Ispytateley Prirody, Byulleten, Otdel Geologii, v. 64 (34), no. 1, p. 93-107, 1959.

[2]This article is an expansion of a paper prepared by the author for presentation before the IV Congress on the Stratigraphy of the Carboniferous in Heerlen in 1958. The basis of the article is a stratigraphic scheme developed by the Commission on the Stratigraphy of the Carboniferous of the advisory preparatory committee for the XXI session of the International Geological Congress.

The basic features of this scheme are: the lower boundary of the Carboniferous is placed along the bottom of the Wocklumerian zone; the Namurian remains unchanged in the interval A-B; the C interval of the Namurian is incorporated into the Bashkirian stage. The upper boundary of the Carboniferous is placed at the base of the Schwagerine bed. The Protvin beds are correlated with Namurian A; suite E of the Donets basin up to the E_8 limestone is correlated with Namurian B.

Stages of lesser significance in brachiopod development are assigned to division boundaries of the Carboniferous, and separate stages coincide with further subdivisions. The correlations which follow are based primarily on the examination of that part of the brachiopod fauna which lends itself to paleontologic study and description.

LOWER CARBONIFEROUS

Tournaisian Stage

At the base of the Carboniferous, during the beginning of the Wocklumerian, Productella, Spinulicosta, Agramatia, Chonopectus, Hypothyridina, and Atrypa die out. Locally, in the Etrenian zone, Cyrtospirifer, Lamellispirifer, Liorhyncus, Gürichella, and other forms still survive. Atrypa, as may be expected, is limited to the Devonian, but in parts of North America it continues to the Kinderhookian, where it has a limited distribution [48]. Buxtonia, Pustulata, Thomasina, Dictyoclostus, Linoproductus, Spirifer, and the subgenus Imbrexia appear. (In place of Thomasina, which is preoccupied - just as Thomasella, which has been proposed in its stead - the name Argentiproductus has been finally proposed; however, because Argentiproductus has not yet received wide usage in the U. S. S. R., Thomasina, which has appeared in the Soviet literature, will be used in this article.) In Kazakhstan, Buxtonia, Pustula, Imbrexia continue to Prolobitan time [12, 21]. In North America, Imbrexia (Spirifer forbesi Norw. et Prat. group) are found only in the Burlington limestone. On the Russian platform, an endemic complex developed; it contains Rugosochonetes, Punctospirifer, and Eomartiniopsis [3, 14, 22] (table 2).

The formation of a new stage in the development of brachiopods can be observed in all the known biogeographic provinces of the Wocklumerian; the new genera are widely distributed in the upper strata of the [lower?] Carboniferous. In the Tournaisian, brachiopods underwent a major stage in development. Spirifers evolved from the primary small and finely costate Spirifer af. S. clathratus Vaugh. and similar forms, appearing in the Etrenian

TABLE 1. Stratigraphic distribution of brachiopod genera in the Russian platform and the western slope of the Urals. These are the most characteristic genera for all of the Carboniferous.

Brachiopod genera	Stratigraphic subdivisions				
	Devonian	Lower Carboniferous	Middle Carboniferous	Upper Carboniferous	Permian
Avonia					
Buxtonia					
Pustula					
Linoproductus					
Cancrinella					
Dictyoclostus					
Marginifera					
Spirifera					
Choristites					

TABLE 2. Species found at the base of the Tournaisian stage in the eastern European biogeographic province

Moscow basin Khovan beds, Malev stratum	Volga-Ural region		Donets basin $C_{1}ta$ zone	Dnepr-Donets depression $C_{1}ta$ zone
	beds commonly containing Endothyra communis Raus	Malev stratum		
Schuchertella planiuscula (Sem. et Moell.)	Schuchertella sp.	Schuchertella sp.	Schuchertella planiuscula (Sem. et Moell.)	Linoproductus cf. panderi (Auerb)
Rugosochonetes malevkensis Sok., Plicatifera fallax (Pand.)	Plicatifera fallax (Pand.)	Rugosochonetes malevkensis Sok.	Rugosochonetes hardrensiformis Rot.	
Linoproductus panderi (Auerb.)	Camarotoechia sp.	Plicatifera fallax (Pand.)	Plicatifera kalmiusi (Liss.)	Paulonia ranovensis (Peetz)
Camarotoechia panderi (Sem. et Moell.)	C. panderi (Sem. et Moell.)	Linoproductus panderti (Auerb.)	Linoproductus panderi (Auerb.)	Martiniopsis cf. waschkuricus Frcks
Ambocoelia urei (Feim.)	Paulonia ranovensis (Peetz)	Camarotoechia panderi (Sem. et Moell.)	Camarotoechia panderi (Sem. et Moell.)	Athyris pectinata Sem. et Moell.
Punctospirifer malevkensis Sok.	Athyris puschiana (Vern.)	Eomartiniopsis elongata Sok.	C. domgeri Tschern.	
Athyris puschiana (Vern.)	A. pectinata Sem. et Moell.	Athyris puschiana (Vern.)	Paulonia ranovensis (Peetz)	
			Martiniopsis waschkuricus Frcks (=Eomartiniopsis elongata Sok.)	
			Ambocoella urei (Flem.)	
			Athyris aff. subpyriformis (Sem. et Moell.)	

strata among the declining Cyrtospirifer and Lamellispirifer [1, 32] as well as the well-known works of A. Vogan and his associates, to highly varied forms typified by the Spirifer tornacensis Kon. group which populated many basins with Spirifer tornacensis (table 3).

transgression of this period.

In Subzone Caninia 1, many members of the Spirifer tornacensis group died out and were replaced by the closely related S. konincki Dew. Among the Tournaisian productids,

TABLE 3. Brachiopod fauna characteristic of the Spirifer tornacensis time in western Europe and the Russian platform

England, Zaphrentis zone	Moscow basin, Cherepet stratum
Rhipidomella aff. michelini (Eveill.)	Schizophoria resupinata (Mart.)*
Schizophoria resupinata (Mart.)*	Leptaena (Leptaenella) analoga (Phill.)*
Leptaena analoga (Phill.)*	Schellwienella burlingtonensis Well.
Chonetes crassistria M'Coy	Chonetes hardrensis (Phill.)*
Ch. hardrensis (Phill.)*	Buxtonia antiquissima (Liss.)
Productus (Dictyoclostus) semireticulatus (Mart.) mut.	Pustula scabriculiformis (Liss.)
Pr. (Dictyoclostus) burlingtonensis Hall	Linoproductus laevicostus (White)
Pr. (Pustula) pustulosus (Phill.) mut.	Antiquatonia znamenskensis (Liss.)
Pr. (Linoproductus) cora d'Orb. mut. Z	Camarotoechia acutirugata Kon. *
Camarotoechia mitcheldeanensis Vaugh. **	Spirifer tornacensis Kon. *
Spirifer tornacensis Kon. *	Sp. taidonensis Tolm.
Sp. penctagonus Kon. *	Sp. pentagonus Kon. *
Sp. ventricosus Kon. *	Sp. ventricosus Kon.*
Syringothyris cuspidata (Mart.)	Syringothyris hannibalensis (Swall.)**
S. cf. typus Winch.	Punctospirifer partitus (Portl.)
S. carteri Hall*	Athyris hirsuta (Hall)
Spiriferina octoplicata (Phill.)	
Athyris glabristria (Phill.)	
A. (Cliothyris) royssii (Eveill.)	

*Forms common both to zone Z of the English Carboniferous and the Cherepet stratum in the Moscow basin.
**Forms believed to be related (Siringothyris carteri Hall and S. hannibalensis [Swall.] or very similar forms) (Camarotoechia mitcheldeanensis Vaugh. and C. acutirugata Kon.).

This group is represented in the Taydon zone of the Kuznetsk basin by S. tornacensis Kon., S. taidonensis Tolm., and other members of this association including Chonetes hardrensis (Phill.), Syringothyris cuspidata (Mart.), S. typus Winch., and Dictyoclostus burlingtonensis Hall [9, 25]. The Spirifer tornacensis group is widely developed in the Rusakov strata of Kazakhstan: S. aff. S. tornacensis Kon., S. incertus Hall; and other members of the complex common to the Carboniferous in England, such as Dictyoclostus burlingtonensis Hall, Syringothyris typus Winch., S. cuspidata (Mart.); and forms common to the Cherepet strata of the Moscow region such as Linoproductus laevicostus White. Just as in England, the first Spirifer ex gr. S. tornacensis Kon. appear in Kazakhstan before they do in the Moscow basin - in the Kassin beds, where they are "very rare, relatively small, and atypical" [8], as in the Cleistopor zone of England.

In the Carboniferous of North America, forms similar to Spirifer tornacensis Kon. have been found; they are S. centronatus White in the Kinderhookian [47]. The wide distribution of the Spirifer tornacensis zone, not only in Eurasia, but also, apparently, in North America, indicates the great extent of marine

Linoproductus and Dictyoclostus became diversified; they originated, apparently, from a common branch, from the first undiversified Linoproductus panderi (Auerb.) (Malevsky stratum in the Russian platform), L. ovatus Hall (Kinderhookian of North America), Productus cora mut. K. (England). The productids developed, toward the end of the Tournaisian, normal members of the genus (Linoproductus corrugatus McCoy in the Z_2 and C_1 zones of the Carboniferous in England, and others). The dictyoclostids and Dictyoclostus cf. D. martini Vaugh. (D. vaughani Muir-Wood) from the K_2 subzone evolved from primitive forms in the Pilton beds in England to typical dictyoclostids of the late Tournaisian. The buxtonids and many other genera underwent the same development.

The brachiopod population of the Tournaisian seas, scattered during the Wocklumerian into separate biogeographic provinces (the western European, eastern European, North American, and other regions), became consolidated to a considerable degree during Zaphrentis time; western, eastern, and central Europe formed a single common province with respect to the Spirifer tornacensis zone, extending to the southern regions of central Asia and even having some effect on the Kazakhstan fauna

(which shows evidence of influence from the North American province as well). Thus, the Tournaisian was an important stage in the development of brachiopods from all points of view.

The Visean

The majority of genera extending from the Devonian into the Tournaisian died out before the beginning of the Visean; some genera, such as Camarotoechia and Plicatifera, continued during the Visean. Daviesiella, Paeckelmannia, Cancrinella, and, very rarely, the first primitive Gigantoproductus appeared at the base of the Visean. The rejuvenation of the brachiopod fauna is clearly reflected in the sharp explosion of species formation. The chonetid and productid species were particularly numerous and diversified [33, 38]. A basically similar brachiopod complex was developed in the Productus sublaevis zone extending from England and Belgium to the eastern parts of the Russian platform, the Donets basin, and the Urals. The wide horizontal distribution of conditions evoking the sharp species diversification, as well as the appearance of forms typical of the Visean, are reasons for establishing the lower boundary of the Visean stage along the base of the Productus sublaevis zone (table 4).

Gigantoproductids and striatiferids, which appeared in the Visean and became extinct soon after the end of this age (analogous to the Namurian), are characteristic of the Visean; daviesiellids and megachonetids became widely distributed; Spirifer trigonalis (Mart.) became the typical group among the spiriferids. During this age, the brachiopods passed through a complex interval of development.

The genus Spirifer, indicating ties with its ancestor Cyrtospirifer during the Tournaisian in the form of a delthyrial plate [Tr.:deltidium?] in many of the Spirifer tornacensis groups (particularly in the young ones) [22], lose this structure completely in the S. trigonalis group. In the course of the Visean, spirifers form several groups distinguished by their internal and external structures: Spirifer trigonalis (Mart.), S. duplicostata (Phill.), S. ovalis (Phill.) (subgenus Ovalis Nal.), and others. Towards the end of the Visean and Namurian A, S. groeberi Schwetz. also appeared in the S. trigonalis groups. From the Russian platform, new data indicating a genetic relationship of the genera Brachythyrina and Choristites with the genus Spirifer s. str., based on internal structure, are being evaluated [18]. M. E. Yanishevsky has written of the variable internal structure of Serpukhov spirifers, although he did not equate this with the development of a new type of internal shell structure [26].

In the Visean, the productids are characterized by an even greater diversity than the spirifers; they are represented by gigantoproductids, productids, antiquatonids, marginiferids, and many other genera. Each genus contains numerous species, replacing each other in time. During the Visean, there is a long development of brachiopods from the early Daviesiella to the possibly related gigantoproductids; the gigantoproductids have developed from the primitive small thin-ribbed Gigantoproductus corrugato-hemisphaericus Vaugh. and such atypical forms as G. ? sarsimbai Serg. [20] in the lower Visean to the characteristic G. giganteus (Mart.) with major longitudinal folds, from subzone D_2 in western Europe and the Russian platform, or G. latiexpansus Sar. from subzone D_3 in the Russian platform (Tarus strata). During the Visean, many other brachiopod genera also underwent a similar prolonged evolution.

According to their brachiopod assemblages, the Visean seas can be divided into two main biogeographic provinces: the Eurasian and the North American. The North American does not contain the gigantoproductids and other forms which are characteristic of the Eurasian [18]. The fauna of eastern and western Europe during the greater part of the Visean is closely related within this province and also with the fauna of several regions in central Asia. Particularly close ties among the European fauna were maintained at the beginning of the Visean, particularly in the Productus sublaevis group, as well as in subzone D_2 and in the beginning of subzone D_3. In subzone D_1, the fauna of eastern Europe was somewhat isolated. In the Seminula zone, no brachiopod facies are present on the Russian platform. The influence of the European province extended also to Asia: to the Fergana, the Alay range, Tien Shan, and farther east. In the Visean facies of China, characteristic European forms are known: Megachonetes papilionaceus (Phill.), Gigantoproductus giganteus (Mart.), Striatifera striata (Fisch.), and others [6, 27]. In the western parts of the Eurasian polar basin, Visean brachiopods (Novaya Zemlya) reveal many forms common to the western European Visean fauna [16, 45, 46].

In Kazakhstan, Visean fauna (Ishim and Yagovkin beds) differs from the European; here, a significant role is played by the endemic element. North American types are found together with some of the European; gigantoproductids are represented by a single species and the spirifers are mostly represented by North American forms [8]. A considerable increase in North American types, with an even greater decrease in the influence of the European province, is observed in the extreme northern part of Asia, Nordvik, and other regions [19]. Thus, the Visean corresponds to an important stage in brachiopod

TABLE 4. Correlation of Tournaisian and early Visean stratigraphic subdivisions in western and eastern Europe on the basis of characteristic brachiopod assemblages [1]

England and Belgium	Russian platform (Volga-Ural region)
Productus sublaevis zone (=Caninia 2 sub-zone)	Malinov Substage
Rhipidomella michelini (Eveill.) Schizophoria resupinata (Mart.) Chonetes gibberulus M'Coy Ch. papilionaceus (Phill.) Ch. dalmanianus Kon. Productus (Pustula) pixidiformis Kon. Pr. (Pustula) pustulosus (Phill.) Pr. (Cancrinella) undata Defr.	Rhipidomella michelini (Eveill.) Schizophoria resupinata (Mart.) Chonetes gibberulus M'Coy Ch. ex gr. papilionaceus (Phill.) Ch. dalmanianus Kon. Pustula pixidiformis Kon. P. pustulosa (Phill.) Cancrinella undata (Defr.)
Spirifer konincki zone (=Caninia 1 sub-zone)	Kizelov stratum
Productus (Pustula) pustulosus (Phill.) mut. Spirifer konincki Dew. Sp. tornacensis Kon. Sp. attenuatus Sow	Pustula pustulosa (Phill.) Spirifer konincki Dew. Sp. aff. attenuatus Sow. Sp. cf. tornacensis Kon.
Spirifer tornacensis zone (=Zaphrentis zone)	Cherepet stratum
Schizophoria resupinata (Mart.) Leptaena analoga (Phill.) Chonetes hardrensis (Phill.) Spirifer tornacensis Kon. Sp. ventricosus Kon. Sp. pentagonus Kon.	Schizophoria resupinata (Mart.) Leptaena (Leptaenella) analoga (Phill.) Chonetes hardrensis (Phill.) Spirifer tornacensis Kon. Sp. ventricosus Kon. Sp. pentagonus Kon.
Kleistopora zone [2]	Likhvin Substage

1. Only those forms are listed which are common to the corresponding subdivisions of both regions.

2. The Likhvin Substage with its endemic fauna should not be correlated with =zone K of England on the basis of its brachiopod fauna.

development; the beginning of this stage is related to the early development of the Productus sublaevis zone. Although the lower boundary of the Visean stage is clearly reflected in brachiopod fauna, its upper boundary is weakly distinguished in this respect.

The Namurian

In typical Namurian stratigraphic sections (Shokye suite or Namurian A in Belgium), the brachiopod content is very small; half of these originate from the underlying Visean Shokye suite, "the transitional beds" [39, 40]. Not one genus dies out along the contact of these beds with Namurian A, not one new genus appears; the genera Productus and Crurithyris, missing in the "transitional beds," occur in the lower parts of the Visean. In comparison with the "Transitional beds," several new species do appear in Namurian A, but they are all known in the lower Visean strata. Only Orbiculoidea missouriensis Schum. belongs to the younger Pennsylvanian complex. Thus, in the Namurian type locality, there is no indication of new brachiopod development at the base of Namurian A. It is quite possible that this is related to considerable degree to the transition from typical marine facies to the Kulm facies.

Namurian A is represented by a typically marine facies in eastern Europe. On the Russian platform, where Namurian A is composed of the Protvin bed, of the 20 brachiopod genera contained in this bed, 19 are widespread in the Visean. Among these are the typically Visean Gigantoproductus, Striatifera, Pugilus, and Spirifer s. str. (Spirifer trigonalis (Mart.) group). Only one genus, Brachythyrina, is a new form in the fauna of this stratum. But the brachythyrinids do not play a major role in any of the subdivisions of the Carboniferous, neither in number of species nor in any significant change through time. Thus, the appearance of brachythyrinids does not have any significance in the development of Carboniferous brachiopods. In the Protvin bed, they are represented by various species. The Protvin fauna is basically characterized by Gigantoproductus, Pugilus, Striatifera, and Antiquatonia.

The species distributed in the Protvin bed have been frequently either directly transmitted from the Visean or were directly related to species of the Visean complex (Serpukhov and Oksk substages) and are not related to forms from younger rocks [13, 18]. Thus, in Namurian type localities (in Belgium, northern

TABLE 5. Comparison of brachiopods in Namurian A of eastern and western Europe (different facies conditions)

Belgium, Shokye suite (after Demanet)	Protvin stratum Russian platform (after Sarycheva and Sokol'skaya, Shvetsov, Semikhatova et al)	Donets basin, suite C_1^3 beginning with limestone C_3 and suite C_1^4 (after Rotay and Aysenberg)
Lingula mytiloides Sow.	Buxtonia mosquensis Ivan.	Chonetes pseudovariolata var. fenia Rot.
Orbiculoidea missouriensis Schum.	Gigantoproductus latissimus (Sow.)	Gigantoproductus edelburgensis (Phill.)
Chonetes laguessianus Kon.	G. superbus Sar.	G. extremus Rot.
	G. protvensis (Sar.)	
Plicochonetes crassistrius minimus Paeck.	G. edelburgensis (Phill.)	Striatifera striata Fisch.
Productus carbonarius Kon.	G. irregularis (Jan.)	Str. strypoides Rot.
Eomarginifera frechi Paeck.	Striatifera magna Jan.	Thomasina margaritacea (Phill.)
E. longispina Sow.	Pugilus moschkovensis Sar.	Th. laticostata (Jan.)
Leiorhynchus carboniferus polypleurus Girty	Productus concinnus Sow.	Dictyoclostus costatus (Sow.)
Martinia aff. glabra (Mart.)	Brachythyrina pinguisiformis Semich.	Linoproductus corrugatus M'Coy
Crurithyris amoena George	Spirifer sulomaenis Semich.	Marginifera subcarbonica Leb.
C. urei Flem.	Sp. lujaensis Semich.	Spirifer (Brachythyrina) varians Rot.
	Sp. pseudotrigonalis Semich.	Sp. bisulcatus Sow.

France, England, and the Russian platform), the beginning of a new stage in brachiopod development does not coincide with the boundary between the Visean and the Namurian.

In the Donets basin, in rocks corresponding to Namurian A, gigantoproductids (predominantly from the group Gigantoproductus edelburgensis (Phill.)) and striatifers are quite extensive in distribution, just as in the Protvin bed, Spirifers are also widely distributed: Spirifer triangularis (Mart.) S. bisulcatus Sow., numerous dielasmas, certain brachythyrinids, and some forms of camarophorias [3, 9]. The fauna is relatively similar to that of the Protvin bed of the Moscow basin, but with certain additional forms. These are commonly local species and varieties related to western European Visean fauna. Some species, unknown in the underlying strata of the Donets basin, are widely distributed in Visean sediments of other localities.

The Namurian basins can be divided into two types. One type, occurring between the Visean and Namurian, is characterized by a mixed environment consisting of typical marine carbonate facies and the Kulm facies (the latter gaining predominance in Namurian A). The second type is characterized by a normal marine regime. With the ascendence of the Kulm facies (Belgium, England), brachiopods decline to secondary importance or die out completely; this has been clearly shown by F. Demanet in typical late Visean and Namurian sections [38]. In typically marine facies (Protvin bed of the Russian platform, the Ural region, and the Urals), brachiopods developed normally. The brachiopods of these two basin types differ appreciably (table 5). These differences are closely related to facies conditions and do not correspond to separate biogeographic provinces but solely to various facies zones.

Namurian marine facies are also known in the Pyrenees [35], in North Africa [31, 34, 36, 37], and in certain other regions. For the most part, the Namurian A (Eomorphoceras [Eumorphoceras?] zone) is recognized in these regions; locally, facies rich in brachiopods occur (Pyrenees), but to the best of our knowledge, these assemblages have not as yet been subjected to paleontologic study and decription, so they will not be examined in this article. (In Scotland, the Namurian is primarily represented by goniatite-pelecypod facies and does not contain brachiopods [30]).

MIDDLE CARBONIFEROUS
Bashkirian Stage

The nature of the change in brachiopod development from the Namurian to the Bashkirian cannot be observed in western Europe, the type locality for the Namurian; here, the facies environment was unfavorable for brachiopod development. Favorable, typically marine conditions during Reticuloceras and early Gastrioceras time prevailed in the southeastern part of the Russian platform, the western side of the Urals, and in the Donets basin; they are also known in several regions of central Asia and, locally, on the eastern side of the Urals.

Locally, in the western Urals, characteristic Visean brachiopod genera, typical of the Bashkirian stage, occurred in Namurian A, but died out or declined to a few rare forms in Namurian B. In the southern Urals, gigantoproductids are absent in the upper part of Namurian A. In the central Urals, they are numerous in Namurian A, becoming rarer in the upper part, and do not continue to the upper part of Namurian B. The Visean group Spirifer trigonalis (Mart.), represented in the later forms Spirifer bisulcatus Sow. occurs in the upper Namurian B and in the lower Bashkirian [17]. Relicts of another Visean group, Spirifer striatus Sow., occur in the lower strata of the Bashkirian stage; this group, together with the genus Spirifer s. str., disappear.

In the Carboniferous of the Donets, gigantoproductids are distributed throughout the C_4^1 suite (upper part of the lower Namurian) but do not extend higher up. The striatiferids die out a little earlier. Spirifer bisulcatus Sow. is characteristic for the suite C_1^4, or the Reticuloceras zone. The genus Spirifer s. str. is absent in the Bashkirian of this region. Productus redesdalensis Muir-Wood, P. insculptus Muir-Wood die out at the lower boundary of the Bashkirian, but among the productids many of the lower Carboniferous bypes persist: P. concinnus Sow., Linoproductus corrugatus McCoy, L. ovatus Hall. Some of the other Lower Carboniferous forms are also present, including Spirifer striatus Sow., Athyris ambigua (Sow.) (quite common) [2, 10]. Rejuvenated forms appear in several regions in the Reticuloceras zone.

The beginning of the Bashkirian (the onset of Gastrioceras time) is related to the development of the genus Choristites, as reflected in the rapid development of the group Choristites bisulcatiformis Semikh. and associated groups C. pseudobisulcatus Fredericks et Rot.; Marginifera schartimiensis Jan., and other forms also appear.

Before the onset of the Bashkirian, in Namurian B, a basic qualitative change took place in the brachiopod fauna. The productids, rapidly expanding in the Bisean and Namurian B, gave way to the spirifers (Choristites). The first suspected "choristite-like" forms are occasionally found in the upper Namurian A of the Donets basin[2]. A more distant forerunner of Choristites, Paleochoristites, is assigned to an even earlier time [22]. But the first typical choristite appeared in the Reticuloceras zone; they are rather rare in the E_1-E_7 strata of the Donets [2, 11] and relatively numerous in the Urals [17, 24]. In the beginning of the Bashkirian, the genus Choristites appeared as a rather highly differentiated group, comprising several branches. These branches underwent a significant stage in development during the Bashkirian: from coarse-ribbed forms having internal structure somewhat similar to Spirifer s. str. to fine-ribbed choristite forms having the same internal structure as Choristites of the Moscovian Stage. In the Donets basin, after the appearance of the more fine-ribbed choristite forms of the Choristites vetus Rot. type [11], the spirifers can be divided into two complexes, changing in time. In the western Urals, the second half of the Bashkirian is also characterized by the finer ribbed Choristites having highly branching ribs, a characteristic of a new group, Choristites uralicus Leb., and the genus Brachythyrina strangwaysi Vern. During the Bashkirian, productids developed much more slowly and retained their older form.

The Bashkirian sea of eastern Europe and central Asia can be divided into regions of various brachiopod assemblages. The Donets basin is notable for a weaker development of the Choristites and a greater variety of marginifers than the Ural region. In the Urals and in central Asia (Fergana), the Choristites are plentiful and varied; in the Urals, the forms are particularly thick ribbed. The group Choristites bisulcatiformis, characteristic of the Urals, is rare in the Donets basin where the group C. pseudobisulcatus Frederiks et Rot. are developed, as are the members of the C. vetus Rot. group. Forms similar to C. vetus Rot. are prevalent in Bashkirian rocks in the northern regions of the Russian platform where they are extended to the Vereisian stratum (according to V. P. Barkhatova). All these differences obviously are related to facies features and partly to the features of the paths of migration; they cannot serve as a basis for the recognition of biogeographic provinces. The basic characteristics of the Bashkirian brachiopods are constant in all of its known localities in the Eurasian biogeographic province. The North American province is distinguished by the apparent absence of Choristites, both in the Bashkirian and in the Moscovian.

Moscovian Stage

The following groups die out at the lower boundary of the Moscovian Stage: Choristites bisulcatiformis Semikh. (individual, atypical varieties continue locally up to the Vereisian beds), C. obrotundus Semikh., numerous productids (Productus concinnus Sow. and related forms), Marginifera schartimiensis Jan., Martinia robusta Semich., Choristites vetus Rot. (the last in the Donets basin), and other forms.

The following forms appear on the Russian platform: Paeckelmannia aljutovica (E. Ivan.), Buxtonia mosquensis Ivan., B. aff. B. piscariae Wat., Linoproductus latiplanus Ivan., Choristites inferus Ivan., C. teshevi A. et E. Ivan.,

and others. This complex also continues (survives) in the eastern regions of the platform, where it includes Neospirifer attenuatiformis A. et E. Ivan. and the Donets forms, Marginifera prolixa Rot., M. bella Rot., M. parva Leb. (M. parvula Rot.); and in the northeastern region of the platform, it contains Marginifera confina Ein. Linoproductus riparius Trd., unknown in the eastern regions, is represented by the divergent form Dictyoclostus okensis Ivan.

The reappearance of brachiopod fauna in the Donets basin at the Bashkirian-Moscovian boundary is gradual; at various layers in the interval between limestones J_3 - K_3, new species are found. A more sharply expressed influx of new forms can be observed at the base of suite K (from data published by A. P. Rotay, [11]).

In the Moscovian, as well as in the Bashkirian, a leading role in the brachiopod fauna was played by the choristite group. These form various branches, partly replacing one another in time and partly contemporaneous.

During the course of the Moscovian, basic changes occurred in the brachiopod fauna. The Choristites underwent a long development from Choristites inferus Ivan. (during the early part of the Moscovian), genetically related to the group C. bisulcariformis Semikh., and from C. teshevi A. et E. Ivan. to C. priscus (Eichw.), the most widely distributed form in the Kashir stratum. The group of C. mosquensis is characteristic for the upper half of the Moscovian stage; it contains various and numerous forms, with a high degree of change from one species to another. In the upper half of the Moscovian, a new group appears: C. trautscholdi (Stuck.). The origin of this group is obscure. Its distribution is closely related to facies environment. In regions where the facies conditions are favorable, it extends to the upper Carboniferous and Permian. The groups Choristites mosquensis and C. trautscholdi have a wide horizontal extent and can be found throughout the Russian platform, in the Urals, in central Asia, and in China (28). Some species belonging to the group C. mosquensis were identified in Indo-China (42). Many branches of the productids also underwent extensive development: linoproductids, dictyoclostids, marginifers. New productid genera, Alexenia and Kutorginella, appeared in the Moscovian stage.

The varied brachiopod development during the Moscovian Stage and the wide horizontal distribution of Moscovian fauna attests to the significant role this Stage has had in the history of brachiopod evolution.

UPPER CARBONIFEROUS
Gzhelian Stage

The lower boundary of the Gzhelian is also the lower boundary of the upper Carboniferous. Numerous species and even whole groups of brachiopods die out at this boundary (Dictyoclostus obraszowiensis Ivan., Teguliferina mjatschkovensis Ivan., Brachythyrina kleini (Fisch.), the group Choristites mosquensis Fisch., and other forms): some of these forms persist in Gzhelian rocks in the northern limb of the Moscow basin, mostly as rare isolated species (Choristites sowerbyi Fisch., C. loczyi Frcks., and others). Along the western slope of the Urals, disappearance at this boundary is more pronounced.

The reappearance of brachiopod fauna at the lower boundary of the Gzhelian Stage is considerable in all regions. New genera Notothyris, Keyserlingina, Hemiptichina, and others appear. Much earlier, the existing genera become widely developed and form a series of new types (Camarophoria, Dielasma, and other forms). The genera Chonetes, Buxtonia, Waagenoconcha, Marginifera, Teguliferina, and the subgenus Proboscidella expanded. New forms appeared connecting upper Carboniferous fauna with Permian fauna. Keyserlingina, the first member of the family Littoniidae, characteristic of the Permian, occurs almost throughout all of the Gzhelian. Only in the northern Russian platform, at the Onega river, has an older species of this family, Keyserlingina plana Ivan., been found. These forms are exceedingly rare in the middle Carboniferous. They are not very common in the Gzhelian either, but two separate species are known in this stage. The productids are extremely numerous and varied in the Gzhelian stage.

Choristitids are not evenly distributed regionally. In the Moscow basin, in the Samara Bend and in the Donets basin, "Samara" choristitids (Choristites trautscholdi group (Stuck.)) are quite numerous. In the Karnian Alps, various forms of Martinia and Enteletes, including Permian types, are present. Linoproductus lineatus Waag., well-known in the upper Carboniferous of the Karnian Alps [43], the Moscow trough [4], and the southeastern Russian platform [15], as well as in other regions, is a widely distributed type of the Permian complex. Among the choristitids of the Gzhelian stage many species are retained, being related with Moscovian fauna. Of the choristitids, again only Choristites supramosquensis var. magna E. Ivan., C. norini Chao with one variation C. cinctiformis (Stuck.) (Russian platform) appears in the Gzhelian stage. The connection with Moscovian fauna is also characteristic for the neospirifers.

In the Ural area, in the lower parts of the Carboniferous, several species of the coarse-ribbed, middle Carboniferous type choristitids are present. Rejuvenation does not occur among the productids, but rather among other genera: Orthotichia margani Derby, Chonetes

uralicus Moell., Waagenoconcha tastubensis (Taschern.), Camarophoria pentameroides Tschern. (23). Thus, at the lower boundary of the Carboniferous, there is a regrouping of brachiopods with a change in importance of such typically Carboniferous genera as spirifers and productids, and the emergence of several new genera, partly Permian forms, and the expansion of other, weakly developed genera.

Orenburgian Stage

Before the onset of the Orenburgian, the majority of brachiopods which had survived from the middle Carboniferous into the Gzhelian Stage died out; almost all of the "Samara" type choristitids died out. In the central part of the Russian platform, in the Orenburgian Stage (Pseudofusuline bed), the brachiopods are extremely scarce [5]; it is quite rich and varied in the upper part of the upper Carboniferous along the western slope of the Urals and within the Uralian region. Many new species, unknown in the lower section, together with the genus Spiriferella, appear. As has been mentioned in the literature (D. L. Stepanov), "spiriferellid" fauna are widely distributed in the upper Paleozoic of Eurasia and occur mainly in the Lower Permian. The most primitive spiriferellids, with simple folds developed on the valves, (the group Spiriferella saranae Vern.), appear in the upper Carboniferous. In the Urals and in the Uralian region, fauna of the late upper Carboniferous is much more abundant and varied than that of the Gzhelian [7, 23]. Among the species appearing at the base of the Orenburgian stage (or in the upper parts of the Gzhelian), the most characteristic are: Waagenoconcha pseudoaculeata (Krot.), W. tastubensis (Tschern.) Camarophoria purdoni Nik., Neospirifer cameratus (Mort.), Choristites supramosquensis (Nik.), Spiriferina ornata (Waag.), Spirifirella saranae Vern., Dielasma elongatum Schloth. [23].

The nature of the Orenburgian Stage with respect to the brachiopod fauna is not completely clear: in this connection, there is an almost complete absence of brachiopods in the Orenburgian of the Moscow basin. Thus, for this Stage, another section will have to be measured as type locality, instead of the Moscow trough which, until now, has been adopted as a type locality for all the Carboniferous.

The major portion of the brachiopod fauna is composed of "Permian type", forerunners of species widely distributed in the Permian. Together with these, a significant place is occupied by the typical Carboniferous forms, such as Chonetes uralicus Moell., Linoproductus cora (d'Orb.), Echinoconchus fasciatus (Kut.), and other forms. The presence of these forms indicates that, in spite of the appearance of younger elements, this brachiopod complex is closely related to Carboniferous fauna and thus belongs to the Carboniferous. Changes in brachiopod fauna at the upper boundary of the upper Carboniferous is not examined here.

CONCLUSIONS

As is indicated by the facts stated above, Carboniferous brachiopod fauna constitutes a single unified whole, tied together by a consecutive development of genetically related groups which are common for all the Carboniferous. Within this major evolutionary cycle, these are two boundaries in brachiopod development: the first at the lower boundary of the Bashkirian stage or at the base of the middle Carboniferous (more precisely, in the Reticuloceras zone), when the leading role was shifted from the productids to the spirifers; the second, at the lower boundary of the upper Carboniferous, when spirifers became secondary in importance and numerous new types and genera came to the fore. The existence of two major breaks or gaps in the evolution of brachiopods, a fauna which plays such a significant role among the marine fauna of the Paleozoic, stresses the necessity of maintaining three divisions in the Carboniferous.

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ON THE BITUMINOSITY OF MESOZOIC SEDIMENTS IN THE TRANSBAIKAL REGION[1]

by

L. T. Klimova[2]

• *translated by Salih Faizi* •

ABSTRACT

The lithologic and stratigraphic relationships of Jurassic and Cretaceous basins of the Transbaikal region are described. Most are fresh-water deposits. Bituminous paper shales and brown coal are significant features of the Lower Cretaceous sequence. Studies made of the bituminous constituents indicate deposition under reducing conditions. Basins of the Transbaikal and Gobi are compared. Prospects for oil are poor in the Transbaikal region. --M. Russell.

The Transbaikal region is broadly occupied by Jurassic and Lower Cretaceous sediments.

The Jurassic rocks consists of marine sediments, well defined on the basis of Lower, Middle, and Upper Jurassic fauna found in broad areas of the eastern Transbaikal region and continental sediments containing peculiar groups of fresh-water fauna and occurring principally in the western Transbaikal region. Continental sediments are as much as 1, 000 meters thick in places. Cretaceous sediments are exclusively continental origin, 400 to 1, 200 meters thick, and contain a fresh-water fauna.

The Jurassic and Cretaceous continental sediments occur in basins which can be divided into four groups according to the age of the sediments:

1) Basins filled exclusively with Jurassic sediments (the Selenga-Itantsinsk basin and perhaps a number of smaller basins nearby);

2) Basins filled with both Jurassic and Lower Cretaceous sediments (Gusinoozersk, Tarbagatai, and, apparently, Bukachachi basins and others);

3) Basins filled in the Lower Cretaceous sediments (Zaza, Vitim, and possibly also Borgoi basins, where oil and bitumen occurrences have been reported);

4) Basins filled with both Lower and possibly Upper Cretaceous sediments (the basins of the Unda and Daya rivers).

On the basis of lithologic composition of the sediments, the basins can be divided into the following groups:

a) Basins composed exclusively of terrigenous sandy-clay sediments or those in which sandy clays prevail (the majority of the basins);

b) Basins in which carbonates, including siderite, were found (Zaza and Vitim basins);

c) Basins in which the usual sedimentary formations prevail but in places enclose tuffs (Argun, Urulungi, Unda, Khudun, and Kijenga basins);

d) Basins largely occupied by tuffs and eruptive rocks (Urov River basin).

It is difficult to make a lithological correlation of the sedimentary horizons of the different basins. The sequence of sandstones, argillites, and silts is not uniform, even within a single basin: sandstones frequently grade into silts, which in turn grade into clays, and so on in the facies relationship. "Paper" shales of Lower Cretaceous age are abundant in some regions and do not occur at all in others; some basins contain eruptive complexes, while others do not.

Lower Cretaceous lake sediments, reported to contain oil bitumens at Borgoi, are the most interesting. Bitumen is unknown in metamorphosed Jurassic continental or marine sediments.

Despite the differing compositions of the sediments, the basins of the Transbaikal region all have certain features in common. The first is that all have a basal conglomerate. However, the conglomerate does not occupy the entire area of a basin: in some cases it is restricted to one side of the basin or is substituted by a coarse-grained basal sandstone. Conglomerates everywhere contain pebbles derived from rocks of nearby mountains. The sections above the conglomerates consist of finer-grained sediments, such as sandstones, silts, argillites, and contain coal beds.

The Jurassic sediments are unconformably overlain by Lower Cretaceous. In some basins, the two sections grade from one to the other with little difference, since the Lower Creta-

[1]Translated from O Bituminosnosti Mezozoiskikh Otlozhenii Zabaikaliya: Novosti Neftyanoi Tekhniki. Geologiya, [News in Oil Technics, Geology], GOSINTI, Moscow, 1958.

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ceous section is also composed of sandstones, silts, argillites, and coal, but in others a basal sandstone or conglomerate separates the two sections. The Lower Cretaceous section contains thinly laminated "paper" shales in its lower part. The upper horizons of the Lower Cretaceous sediments contain economic deposits of brown coal.

The study of the Jurassic and Lower Cretaceous sections in different districts of the Transbaikal region permitted us to distinguish the following types of sediments:

1) Sandstones composed of quartz, feldspars, mica, polymictic and tuffaceous rocks;

2) Silts which may be shaly or sandy-shaly, rarely sandy;

3) Limestones in rare thin beds;

4) Marls and siderite rocks. The latter occur in the form of separate beds or large concretions (only in the Zaza and Vitim basins).

The Jurassic and Cretaceous sediments have two kinds of argillites. In one, composition is not uniform; some parts consist of finely dispersed clay containing fine organic fibers. These parts consist of clastic accumulation and plant remnants with admixed terrigenous matter. From among the authigenic minerals we found pyrite in the form of scattered fine crystals, siderite, and biotite.

The second type of argillites is uniform and light grey in thin section under the microscope. It contains fine sheets of clay-and-mica minerals and chlorite or their aggregates. The argillites frequently are thinly laminated as a result of parallel orientation of fine-scaled aggregates. In places they contain fibrous brown organic material or laminated coal.

The Mesozoic argillites of the Transbaikal region can be included in the group of montmorillonite clays found in the districts of Tarbagatai, Bais, and Kharanor. Beside the montmorillonite clays, we found beds in which the clay fraction consists principally of montmorillonite, called beidellite by some geologists. These argillites occur in the Arbagar deposit and along the Bais and Vitim rivers. Finally, some argillites consist of hydromicas and montmorillonite (Zaza and Arbagar rivers and the district of the Chernovsk mines). None of the argillites contains kaolinite or other minerals of the kaolinite group. We may assume, therefore, that the sediments were formed in slightly alkaline environments. A part of the hydromica was perhaps formed as a result of montmorillonite alteration.

Oil explorers are interested principally in "paper" shales. These shales are outwardly very uniform, grey (dark grey, if wet), brittle and thinly laminated. The bedding planes frequently have impressions of fishes, insects, or other fauna. The "paper" shales are underlain by argillites, silts, or marls. According to data available on the physical composition, the "paper" shales comprise 40 percent of the silt fraction. This fraction contains grey organic material and coal laminae irregularly distributed in the clay material. Calcite and pyrite can be seen along with the grey organic material. The clastic part of the rock includes quartz fragments and feldspars.

Thermal and electron-microscopic studies and chemical assays provide exact data on the composition of "paper" shales. They reveal that the mineral composition of "paper" shales, does not differ from that of argillites. Like argillites, "paper" shales consist of montmorillonite or other minerals of the montmorillonite group, or of hydromicas with admixed minerals of the montmorillonite group.

The studied samples can, on the basis of mineral composition, be divided into two groups: argillites and "paper" shales of montmorillonite composition and argillites and "paper" shales composed of montmorillonite and hydromicas.

The "paper" shales are inflammable. This property was interpreted by some investigators as being indicative of bitumen content or even of a possible original oil formation in these shales.

V. G. Putsillo undertook bituminological studies of argillites from various districts of the Transbaikal region in order to clarify the nature of the bitumen content in Lower Cretaceous "paper" shales and argillites. The organic matter comprises 40 percent of the shales from the Lake of Gusinoye, while the bitumen extracted by chloroform comprises about 2 percent. The shales contain about 6 percent humic acid, consisting of 61.8 per C and 5.14 percent H. Highly complicated and simple derivatives of pyrrole were not found in the bituminous shales at the Lake of Gusinoye.

The bitumen content of the shales of the Vitim district and of the "paper" shales of the Sutai River is higher. However, according to luminescence analyses, they contain largely coal bitumen. V. G. Putsillo, who investigated the shales and argillites, points out the differing solubility of the organic substances found in shales. For example, the shales of Gusinoozersk, of the Sutai River, and at the village of Romanovka contain bitumen, extractable by chloroform (up to 1.5 percent), in greater amount than do the shales of the Turkhul district, Bais, and Jidotoi (up to 0.40 percent).

All the bitumen is black. The bitumen extractable by chloroform is waxy, while that extracted by spirits of turpentine and benzol is hard and brittle.

For comparison, bitumen of coal was also analyzed. The coal of the Gusinoozersk deposit contains essential amounts of the bitumen extractable by chloroform, spirits of turpentine, and benzol. This bitumen has a low H content and a high C:H ratio (9:1), and, like coal bitumen elsewhere, a high lathering capacity. Similar bitumen in the shales of Turga and Vitim (Bais) has a higher H content. However, its acidity and lathering capacity does not permit us to consider it as oil bitumen. The bitumen of shales extracted by spirits of turpentine and benzol has a higher oxygen content, and a relatively lower carbon and hydrogen content. This indicates a typically acid composition.

As result of her studies, V. G. Putsillo concluded that bitumen extracted from shales and argillites of the Transbaikal region is in some cases close to coal bitumen and in other to oil bitumen. This conclusion is also confirmed by the examination of compounds extracted from the bitumen of shales and coal.

In view of these characteristics, we may assume that the bitumen of some shales was formed under more pronounced reducing conditions than of others. However, in this case we have to keep in mind that the shales cropping out in many districts of the Transbaikal region are weathered. V. G. Putsillo believes that the organic substance of shales should be altered additonally to produce typical bitumen, since at the present stage of alteration the bitumen of shales contains substantial amounts of wax in some cases.

The bitumen of shales is of a transitional type between that of coal and oil.

A drill hole in the basin of Borgoi recovered a sandstone bed with 1.23 and 2.23 percent bitumen of high carbon and hydrogen content, a low C:H ratio, and containing paraffins. The origin of this bitumen is, according to V.G. Putsillo, not related to that of the bitumen of the "paper" shales.

Some geologists attempt to draw an analogy between the geological circumstances of the Transbaikal region and those of the Gobi Desert and, on this basis, consider the Transbaikal region as having good prospects.

We have to remember that the Transbaikal region is occupied by Jurassic and Lower Cretaceous sediments but the Gobi is occupied by Jurassic, and Lower, and Upper Cretaceous sediments. The thickness of the Jurassic and Lower Cretaceous continental sediments in the Transbaikal region is approximately one-third those in the Gobi Desert. Besides, the size of the basins filled in with Jurassic and Lower Cretaceous sediments is much smaller in the Transbaikal region than in the Gobi. And finally, the Lower Cretaceous sediments in the Gobi Desert undoubtedly includes shales having oil bitumen.

Since the origin of the bitumen of the Lower Cretaceous shales is related to that of the oil-bearing beds of the Gobi Desert, these shales are perhaps rocks where oil was originally formed.

But this is not true in the case of "paper" shales, the bitumen composition of which differs sharply from that of the Gobi Desert.

Thus, according to the above data, the Mesozoic sediments of the Transbaikal region can hardly be economically oil-bearing.

ON THE CLASSIFICATION OF VARIOUS BEDDING TYPES[1]

by

L. N. Botvinkina

• *translated by P. F. Moore* •

TRANSLATORS NOTE:- The following translation gives the latest (1957) Soviet thinking on classification of bedding structures.

Botvinkina gives a brief historical review of Russian work on the classification of bedding types and subsequently produces his own scheme; within its acknowledged limitations, the Botvinkina classification covers the field very fully, and, is descriptive and objective. The classification, however, seems somewhat too idealized; one feels that it has been insufficiently tested against actual outcrops. This is ironical in that most current Russian writing lays particular stress on "concreteness".

A recent Soviet article on stratification offers tacit criticism of such a purely morphological approach as Botvinkina's. N. B. Vassoyevich (in his work: "Bedding in the light of the doctrine of sedimentary differentation," 1955) points out that there is an organic connection between the type of stratification and the composition of the sediment. All sediments are arranged in a sequence which begins with coarse detritus and ends with chemical sediments: the former are characterized by inclined bedding; the latter, by horizontal bedding. Vassoyevich also draws attention to the old controversy about migrating sedimentary facies and the resultant diachronism of strata. This view has been opposed generally by the school which regards bedding planes as synchronous breaks in deposition. How, they ask, can gradual migration of a facies boundary give rise to a bedding plane? Vassoyevich answers that the mechanical properties of sediments are not part of a continuum, but are subject to breaks. A certain grain size separates sediments normally moved by rolling from those moved by saltation; another separates the latter from sediments carried in suspension. This is the dialectical principle "transformation of quantity into quality". It can explain why there are fairly sharp boundaries between lithotopes on the sea floor and how diachronic bedding plane could come into being.

Another dialectical principle introduced by Vassoyevich is "unity of opposites". He shows, in development of stratification, how evolutionary and revolutionary factors are a work and how they interplay in production of the sedimentary series with its combination of migratory and disconformable stratification.

The main lesson to be learned from his study is the close interplay between lithology and structure. Botvinkina ignores lithology except as it contributes directly to structure (mica-flake partings; grain-size variation producing bedding, etc.). He cannot do this on grounds of subjectivity since it is as objective a characteristic as the structure. I conclude that insofar as bedding is linked with sedimentary differentation no objective description of sedimentary structure is complete without petrographic description.

With reference to the details of Botvinkina's scheme, it is not clear what function the triangular diagram is supposed to perform. It is quite illogical and has at its corners three characteristics which are not members of the same class; it appears to have been taken over from the old literature. 'Wavy', 'straight', and 'curved' are members of a class designating form. 'Horizontal' and 'inclined' are members of another class designating orientation. He has taken two characters from one class and one from another and attempted to combine them. Fortunately, when he comes to the main development of his scheme, the triangle is dropped from discussion; and, in the table which sums up his conclusions, the error is corrected.

Another necessary amendment would bring disturbed bedding and lack of bedding into the scheme; Botvinkina is well aware that he has not dealt with these factors. They should however, be introduced as primary categories in his first group of criteria to leave the way open for separation into subtypes as our studies develop. Thus, the first group would be: 1) Rectilinear 2) Bowed 3) Wavy 4) Disturbed 5) Absent.

Botvinkina's summing up on the subject of genetic classification is in line with more recent con-

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[1] Translated from Uver die Klassifikation verschiedener Schichtungstypen: Zeitschrift fur angewandte geologie, no. 1, p. 39-44, 1956.

clusions of our research workers that structual criteria for sedimentary environments lie in the sequences and associations of bedding types not in any uniqued equation between bedding type and mode of origin. -- P. F. M.

ABSTRACT

The author presents his classification of bedding types for sedimentary rocks. Several earlier classifications reviewed here have not been adequate for standardization of terminology or classification. Analogeous bedding types have been found to occur in rocks of varied origin , so that it has been difficult to formulate classifications based solely on the genesis of structural types; conversely, a purely structural classification is, as well, inadequate. A classificiation proposed by Zhemchuzhnikov in 1926, was organized according to bedding form (type) and bedding dimension (subtype). In 1940, he revised his classification stating that all distinguishing criteria of bedding could be arranged in three groups: a) criteria displayed by individual beds; b) criteria peculiar to bedding sets, and c) criteria indicative of the cause of bedding. The author uses these criteria as the basis for his proposed classification. The first two groups are structural criteria; the third, genetic. A fourth category of the Zhemchuzhnikov classification, including conditions for stratification, is incorporated under group three. Hypothetical examples illustrating use of this classification to describe three types of sedimentary deposits are given. Additional research according to the author is necessary on classification of unbedded structures as well as on preparation of a unified genetic classification of structures. --D. D. Fisher.

In the study of the sedimentary rocks, increasing attention is being devoted to the complex of those factors which characterize conditions of formation of the primary sediments.

In many, principally lithological, works the importance of structural as well as textural characters of rocks has been emphasized. [Tr.: German Struktur has been translated "texture" and German Textur has been translated "structure"; this is in accordance with the common English petrographical and sedimentological use of those terms.].

Whereas several detailed classifications have been devised for textural characteristics of sediments or rocks, (these, in general are rather similar to each other, M. S. Shvetsov [5], 1948: L. B. Pustovalov [4], 1940), no complete classification exists for structural characteristics; hardly any effort has been made to investigate from this point of view various types of structure.

Structure, especially bedding structure, is an extremely important factor in determining genesis of sediments.

In earlier works it was customary to describe sedimentary rocks either unbedded or horizontally bedded; all other bedding types were grouped together under the general heading of inclined or diagonal bedding.

In Soviet Literature, Yu. A. Zhemchuzhnikov [2] was the first to direct attention of researchers to the importance of oblique bedding. In his work (1926) on the genetic importance of various types of inclined bedding, he separated five genetic bedding types and gave identifying characteristics for their diagnosis in nature.

This article, outstanding from the point of view of content and subject matter naturally could not cover the whole range of sedimentary-structure types.

Zhemchuzhnikov [3] in an article (1940) introductory to the symposium on "Inclined beds and their geological interpretation" improved and enlarged upon his 1926 account. However, even this collective work must be considered merely as material for study.

Since 1926, many works have appeared in which beds are classified in one way or another and are related to the origin of the rocks. In that none of these works contains any sort of generalization each investigator is obliged therefore to name and describe the beds according to his own opinion. Thus, one bedding type often has various designations.

On the other hand, various bedding types including 'wavy' were grouped with the single classification of 'inclined beds'.

A single type often is eliminated according to completely different criteria; what is more, the greater part of them within one work. Thus for example, in one article of the symposium on "Inclined Bedding" (1940) the following bedding types were named: Interrupted (based on the criterion of continuity of discontinuity of beds); wavy-discontinuous (here also, the criterion of continuity is used with that of the form); mixed (based on the criterion of complexity); horizontal (based on the criterion of form); and microbedded (based on the criterion of size).

In a series of works of the Symposium, significance of the types of inclined bedding given incorrectly with respect to formation con-

ditions of the genetic types (seashore bedding, alluvial bedding, delta incline bedding, etc.)

Theoretically, three types of bedding origin are possible: 1) one type of bedding for a specific rock genesis; 2) one bedding type for rocks of varied genesis; and 3) various bedding types for similar sedimentary conditions.

On the basis of the foregoing material (combined with personal observations as well as the study of relevant literature) it can be said that the first type of bedding is not observed in actuality, or that we perhaps do not yet understand the bedding types with sufficient precision; thus, we have no thoroughly worked out, unified, genetic classification of structures. On the contrary we have observed similar, or at least analogous, types in rocks of varied genesis and have noted varied types of structure in the same sedimentary environment.

While no equation can be established between bedding type and rock genesis, rock genesis cannot be established by structural criteria alone. Structure, in this case the bedding, is, as a result of this conclusion, a useful but not sufficient element [for diagnosis of genesis, PFM].

So, as long as a worked out and practice-proven genetic classification of bedding types is wanting, too much subjectivity enters into designations such as 'fluviatile-bedding', 'seashore-bedding', etc.

In the year 1941 [Tr.: The text gives 1914, the bibliography 1941] a bedding nomenclature for sedimentary rocks was proposed by a group of authors based on the morphological principle. It is comprised of four groups: a) horizontal beds b) inclined beds c) wavy beds d) combined bedding types.

However, the combined forms united the first three and could therefore not have equal value. In each of these groups various types were established which were characterized, moreover, on the basis of various principles. So, for example, in the group of 'horizontal beds' one type was separated on the basis of the bedding form the second on discontinuity, the third on inter-relationships of the beds and so on. In the group of wavy beds, in fact, there was in one type a component part of the others (synclinal and anticlinal bedding are merely elements of unadulatory bedding, not separate types). Lastly, the types they produce failed by a wide margin to include all existing bedding types.

How then should one go about the classification of sedimentary structures?

In our opinion, the classification must be built on a unifying principle: an essential character must designate the type; while sub-types and varieties must be separated on the basis of secondary characteristics.

Exact distinguishing characters, on which it would be possible to base a genetic classification are lacking at present; too subjective a solution to this problem would lead to the situation where genetically distinct bedding types were brought together as similar and vice versa. L. W. Pustovalov [4] also came to this conclusion in his work (1940).

A genetic classification must be preceded by a classification dependent on objective criteria, thus permitting measurement and investigation and at the same time connected functionally with the genesis. Form and dimensions of strata are these criteria.

In most cases, various sedimentation conditions lead to accumulation of bedded deposits which can be either subaerial or aqueous; the former type is quite rare in the fossil state. The great mass of fossil sediments was deposited in aqueous basins (seas, oceans, etc.) or through the agency of an aqueous medium (rivers, intermittent streams, alluvial cones in the mountains, etc.). Through a series of criteria of which the bedding is the most important, the character of the environment of deposition can itself be determined by establishing the character and intensity of motion of the medium. Form of the bedding reflects the character of 'The' medium; dimension reflects the intensity.

Form and dimension, characteristics which are without exception common to all bedding types, can be measured; hence, they can be expressed quantitatively and are therefore unequivocal objective criteria.

Form of the beds is taken as the foundation for the definition of types: the relation of beds and their sets to true bedding planes (Flozfuge).

On this basis the bedding form can be divided into three types: inclined, wavy, and horizontal: Accordingly, the bed is to be described as 'inclined' when a series of beds (straight or bent) follow each other making various angles with true bedding planes; as 'wavy', when the series of strata form wave-like lines oriented parallel to the true bedding planes; and as 'horizontal', when the beds are linear and are oriented both parallel to each other and to the true bedding plane.

Inclined beds accumulate principally by unidirectional activity of the medium; bedding follows this direction and generally indicates the flowing of water (river, marine currents) or the activity of wind.

Wavy beds are built up by agents with varied or opposed directional waves, e. g., ebb and

flow, (for example shallow sea-shores).

Single thin beds of inclined or wavy beds constitute groups, or bedding sets, which have been deposited by a movement maintaining its direction over a period of time. Change in conditions gives rise to accumulation over a period of time. Change in conditions gives rise to accumulation of another bedding set which lies on the earlier set in one way or another.

Horizontal bedding is the product of relative stability, or calm in the depositional medium (deep sea sediments, lacustrine sediments and the like, as in near-bottom beds where water movement is absent or very weak). Of particular importance for this type, where motion is absent as a regulating factor, are criteria such as the amount and size of materials. Hence, that variation of the bedding sets in horizontal beds is conditioned by change in conditions and nature of sedimentation fall-out is often hard to distinguish.

Thus, a coarse designation of bedding types by form only certainly restricts the number of the conclusions which can be drawn as to sedimentation conditions.

However, in nature there are in many cases complicated movements in the medium with various preponderant directions of movement. It is natural, then, that transitional bedding types also occur: wavy-inclined, horizontal-wavy, or flat-wavy, i. e. horizontal with inclined elements.

All possible types of form can be studied on the triangular diagram (fig. 1).

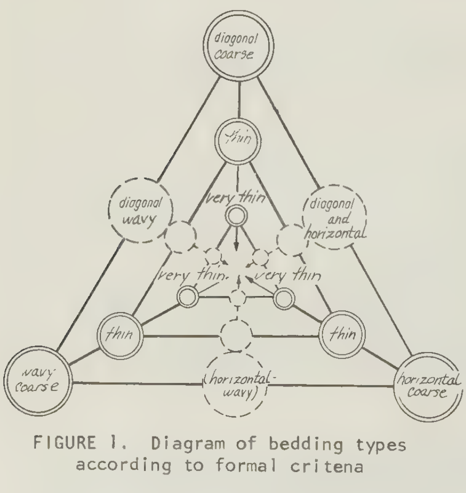

FIGURE 1. Diagram of bedding types according to formal critena

The apices of the triangle display the basic bedding types in their pure form. The sides of the triangle show the transitional types established as a result of the influence of various activities in connection with change in character of the motion [Tr.: See criticism of this scheme in TRANSLATORS NOTE. PFM.].

All possible morphological types of simple bedding are displayed on the triangle; there cannot be other types because there are no movements of the medium which might produce other forms of bedding. Moreover, the only complex forms which can be produced are those composed of simple types lying under one another in section; accumulated in response to changes of sedimentation over a period of time.

For example, Zchemchuzhnikov mentions in his work (1926) that an alternating sequence of horizontal and inclined beds bear witness to deposition by an intermittent current. The inclined parts of the bedding indicate currents of stormy rain periods; and the fine-grained horizontal beds, the periods of relatively quiet conditions (possibly lacustrine conditions).

The second bedding characteristic, dimension of the beds, is the basis for separation of sub-types. By dimension of the bedding is understood thickness of the bedding set or amplitude and length of the waves; these are functions of the intensity of motion and supply of material. The beds can be very thin, occupying a fraction of a millimeter, or coarse, when thickness of the set is measured in meters.

In practice, the following threefold division of bedding according to size is preferred:
1) Coarse, the thickness of the sets reaches a few decimeters and (less often) a meter;
2) Thin, the thickness is only a matter of centimeters; 3) Very thin bedded, thickness of the sets in approximate millimeters. In the horizontal type, very fine bedding is often recorded as "thin". Coarse bedding can only be observed in outcrop; in cores only part of this type is visible. In addition it is worth distinguishing a "microbed", which is visible only under the microscope and which has an extra special importance for the horizontal types.

Besides giving the general designation, one must, in describing the bedding, of course give the measurable characteristics: thickness of individual beds, amplitude and wave-length, thickness of the set, angle of inclination of beds, etc.

The size variation of the subtypes is shown similarly, in Figure 1, by lines leading to the center of the triangle. Thus, for each type (whether basic or transitional) there are three subtypes according to coarseness.

Type	Bedding Form
Basic types	Inclined, wavy, horizontal
Transitional types	Inclined-wavy, horizontal-wavy

Subtypes (for each type)	Dimensions of the bedding
Coarse bedding	A few decimeters and meter
Fine	Centimeters
Very fine (thin)	Millimeters

As Zhemchuzhnikov [3] (1940) further pointed out, the form of the bedding alone (the bedding structures alone) does not yet determine the origin of the rocks: to classify this, the type must not only be characterized by form and size but by other criteria as well. Bedding criteria are grouped in various types of combinations often characteristic of the various types and sub-types. Each complex of criteria helps to distinguish varities which bear witness to this or that genesis of the rocks.

All the distinguishing criteria of bedding can be arranged in three groups: a) Criteria displayed by individual beds; b) Criteria peculiar to bedding sets; and c) Criteria which show what the bedding is caused by.

The first group of criteria distinguishes the beds of a set (fig. 2). These criteria are as follows:

1. Form of the beds can be straight or curved; in the latter case it can be bowed or wavy.

2. Interrelations of the beds can be either parallel or divergent. A variety of divergent strata, when the base of one bed as it were underlies the base of the others, sometimes is designated subjacent beds. [Tr.: I'm afraid the meaning of this is not clear.

3. Steepness of the beds is given by the angle of inclination in inclined beds and by the steepness of waves in wavy beds. Zhemchuzhnikov [3] designated a bed with an angle of inclination up to 20-25°, as flat. In wavy beds this is the angle measured between the wave path and a line to the apex.

In practice, however, such a wave designation is very unusual and the steepness of waves is designated simply by the relationship of wave length to amplitude. Thin beds can be designated 'flat' when this ratio is more than 1:10-12; when it is less, bedding is described as steep.

4. According to the character of the bedding partings stratification can be either transitional or interrupted. That is an important measure, dependent on the amount of fall-out and the materials composing the bed. If there is sufficient material (e.g. detritus, clay particles) to cover the entire surface of the previous bed, then continuous parting appears in section. If there is an insufficient supply of materials it only settles in places and gives a 'streaky' line.

5. Bedding boundaries are sharp if the material composing the beds is very varied; they are distinct when the composition is similar but boundaries of the beds can be determined with sufficient accuracy. Gradual transition from one bed to another is observed when the features

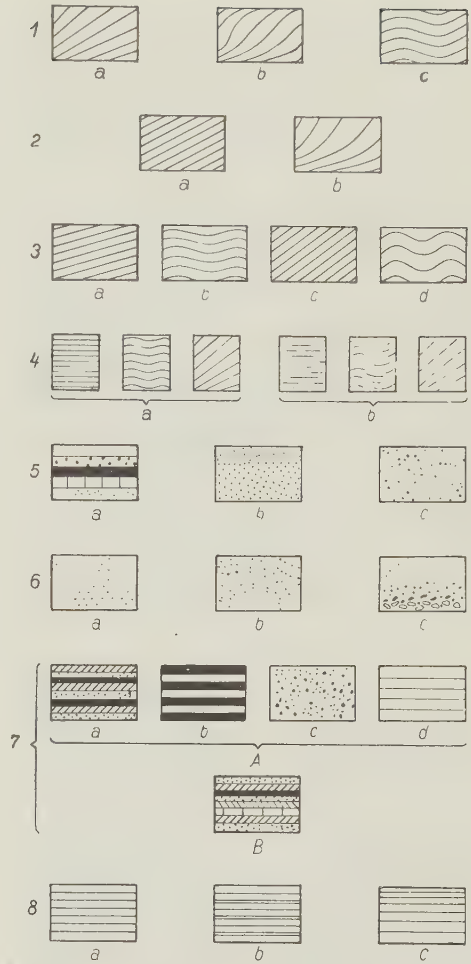

FIGURE 2. Criteria characterizing the beds of a set

1. Bedding form (a) rectilinear (b) bowed (c) wavy.
2. Interrelations of beds (a) parallel (b) divergent (subjacent).
3. Steepness of bedding (a) flat diagonal (b) flat wavy (c) steep diagonal (d) steep wavy.
4. Condition of bedding planes (a) continuous (b) interrupted.
5. Clarity of bedding boundaries (a) sharp (b) distinct (c) gradual.
6. Grain-size distribution of beds (a) homogeneous (b) heterogeneous (c) gradual change in granulometric composition.
7. Sequence of beds.
   A. Rhythmic
      (a) complex (b) bonded (c) recapitulated
      (d) thin partings in homogeneous strata.
   B. Variegated or random sequence (arhythmic)
8. Uniformity of beds and thickness (a) equal thickness (b) unequal thickness (c) grading in thickness.

characterizing the beds are gradually and uniformly altered (e. g. gradual coarsening of the materials).

6. Grain-size distribution of a bed can be of various kinds: homogeneous, nonhomogeneous, or a gradual increase of material.

7. Sequence of beds can be either rhythmic or random. Rhythmic sequences can be distinguished according to the character of the change in the strata: a) complex, if groups of several beds are arranged in a fixed order, e. g. medium grained sandstone, fine-grained sandstone, silt, and then repetition of the series; b) banded or striped beds if two beds alternate; c) recapitulated, if beds are built of material which grade from one type to another; d) sequence of homogeneous beds with thin partings.

8. Beds can be 'uniform' in thickness generally of equal thickness; and of varied thickness, if thickness of the beds is varied and 'gradually changing' with progressive increase or reduction in thickness from the lowest to the highest bed.

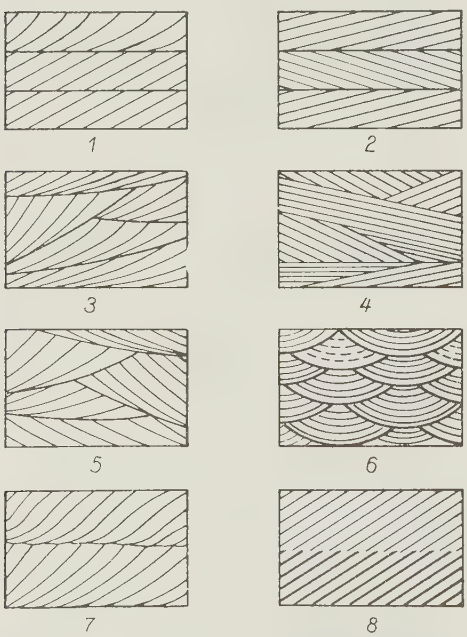

FIGURE 3. Criteria which distinguish bedding sets

1. Parallel; unidirectional sets.
2. Parallel; multidirectional sets.
3. Unidirectional mutually truncating sets
4. Multidirectional mutually truncating sets.
5. Cross-bedded inclined bedding.
6. Cross-bedded wavy bedding.
7. Boundary of the sets is sharp.
8. Boundary of the sets is distinct.

The second group of criteria (fig. 3) distinguishes the bedding sets in the following way:

1. In their mutual relationships bedding sets can be parallel or mutually divergent; in the latter case, part of the underlying series is eroded before deposition of the overlying series.

2. Directionally, beds in neighboring series can be distinguished as multidirectional or unidirectional. The multidirectional beds often are described as cross-bedded because the bedding planes cross each other. In some cases the expression cross-bedded is applied to bedding with truncating sets. It seems to us that one should apply the term cross-bedding to diagonal or inclined bedding only in the case of mutually truncating multidirectional beds. However, if the inclined beds, on the one hand, only alter the angle of inclination (from 0-90^{o}) then we have mutually truncating unidirectional bedding, not cross-bedding.

Wavy beds must be placed in the category of cross-bedding when there is a similar waves truncation in which the overlying wave makes a crosslike form with the crest of the underlying wave.

3. According to their clarity, boundaries of sets can be either sharp, distinct, or gradual: they are sharp when the bedding planes of the set are clearly to be recognized (fig. 4); dis-

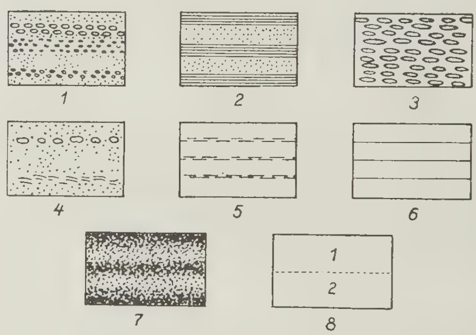

FIGURE 4. Criteria which show what causes bedding

1. Grain-size alteration.
2. Sequence of beds of varied composition.
3. Horizontal orientation of particles.
4. Horizontal layers of various material, e.g. concretions, pebbles, fauna.
5. Thin bedlike scattering of plant detritus or mica.
6. Thin partings in homogeneous rocks (or bedlike influx of clay material).
7. Varied color of rocks.
8. Varied chemical composition (e.g. bed 1 fizzes with acid; bed 2 does not).

tinct, when one can follow the bedding plane more or less convincingly in one place though no sharp boundary of the sets is present; grad-

ual, when one set changes over to the other without a break.

The third group of criteria (fig. 4) shows how bedding is brought into being; particularly bedding associated with falling sedimentary material. Pustovalov [4] describes four causes of bedding:

1. Grain-size alternation (for instance, fine-grained and coarse-grained sandstone);

2. Alternation of beds of varying compositions;

3. Horizontal orientation of (component) particles;

4. Areal layering of any type of materials (concretions, pebbles, debris, shells, and similar objects).

Zhemchuzhnikov names, in addition, conditions for stratifaction, as follows:

1. Fine strewing of plant detritus or mica flakes;

2. Thin clay partings on bedding planes (in such cases, a homogeneous rock breaks into plates on being struck;

3. Variation in color of cement of the sediments.

In this category also belongs bedding conditioned by variation in chemical composition of the cement. The variation in the chemical composition of the cement often calls forth a change in color, so that these two characteristics generally are found together.

It must be said that form of the bedding is not always regular: Often we see no clear, inclined, wavy, or horizontal lines; merely a vague direction whose conditioning criteria, by which they could be assigned to one bedding form or another, escape us.

Random bedding, i. e. bedding that has been insufficiently ordered by sediment fall-out, must not be confused with disturbed bedding originally of definite form but later disturbed after deposition; often, after consolidation of the sediments. A similar disturbance of primary bedding can occur also as a result of solifluction, mud-boring organisms (worms and molluscs) penetration of plant roots into the soil, etc. Up to the present time, these disturbed structures have been but little investigated.

Structures of this type, in which the primary bedding has been altered or destroyed over a considerable thickness, are best treated together with unbedded structures; separation of the types of unbedded structures and structures with disturbed bedding is an important problem. However, we have restricted ourselves in the present treatment to consideration of definition, of bedded-strata types. That does not mean, however, that one shouldn't give attention to structures with disturbed bedding. They often have great genetic importance, since they allude to the conditions in which the sediment found itself immediately after its deposition.

All the criteria of bedding structure described above can be consolidated in the following outline:

I. Criteria which distinguish beds of one set.
  1. Bedding form
    (a) rectilinear
    (b) bowed
    (c) wavy
  2. Inter-relation of beds
    (a) parallel
    (b) divergent
  3. Steepness of the beds
    (a) flat
    (b) steep (give angle of inclination in inclined bedding; and in wavy beds, relationship of wave length to amplitude).
  4. Condition of bedding planes
    (a) continuous
    (b) interrupted
  5. Clarity of bedding planes
    (a) sharp
    (b) distinct
    (c) gradual
  6. Grain-size distribution in the beds
    (a) homogeneous
    (b) heterogeneous
    (c) gradual change in granulometric composition
  7. Type of bedding sequence
    (a) Rhythmic
      (1) complex
      (2) banded (couplets-PFM)
      (3) recapitulated
      (4) homogeneous rock sequence with bedding partings
    (b) Random (nonrhythmic)
  8. Homogeneity of beds with regard to thickness
    (a) uniform
    (b) varied
    (c) gradually changing (increasing and decreasing)
II. Criteria which distinguish bedding sets.
  1. Interrelation of bedding sets
    (a) parallel
    (b) mutually truncating (cross bedding a special case)
  2. Direction of bedding in neighboring sets
    (a) unidirectional
    (b) multidirectional
  3. Clarity of boundaries of the bedding sets
    (a) sharp
    (b) distinct
    (c) gradual
III. Criteria which show how bedding is determined
  1. Grain-size variation

2. Sequence of various beds with differing composition
3. Horizontal orientation of particles
4. Areal dispersion of various materials
5. Fine distribution of plant remains or mica in bedlike form
6. Thin clay films on the bedding partings
7. Varied rock color
8. Varied chemical composition

If the outline above is followed and each character observed, one can describe various bedding types according to a unified scheme. The description will go something like this:

1. Inclined bedding, coarse; beds rectilinear, parallel; angle of inclination, 20-30°. Bed boundaries continuous, distinct. Internal grain size distribution of the bed gradually altering, recapitulated in the following beds. Thickness apparently uniform. Sets parallel, unidirectional, set boundaries sharp. Bedding is caused by change in the granulometric composition.

2. Inclined wavy bedding, fine, interrupted. Clear bedding boundaries, homogeneous grain size distribution, thickness varied. Bedding sets mutually truncating, multidirectional. Set boundaries gradual. Bedding caused by strewing along the beds of fine plant detritus.

3. Bedding horizontal, thin. Beds rectilinear, parallel, continuous. Bed boundaries clear, uniform grain-size distribution. Bed sequence, banded. Uniform bed thickness. Bedding caused by alternation of beds of clay and silt composition.

Each type bespeaks a particular sedimentary relationship. Thus, the first example designates beds of a river channel deposit; the second exemplifies one of the bedding types which characterizes rock laid down at flood time on alluvial plains; bedding described in the third example indicates lacustrine sedimentation, etc.

Genetic investigation of rocks cannot do without the study of stratification as one of the more essential genetic criteria. The circumstance that bedding is no sole criterion for designation of rock genesis reduces in no way its importance and does not obviate the need for furthering its classification.

I have assembled this scheme of morphological classification on the basis of a few investigations on coal-bearing strata in the Kusnetz and Donetz basins and from the literature. Obviously, this scheme is not exhaustive but it can clearly bring some order into the terminology of bedding forms and into description of visible bedding characteristics.

Distinction of bedding types according to a unifying principle and their description according to a unified scheme, with actual reference to the connection of these bedding types with other rock characteristics (texture, flora, fauna, chemical composition, etc.) will help the sedimentary geologist to study conditions of rock genesis on an objective basis.

Unification of the bedding-structure terminology facilitates comparison of the works of various authors in various areas and for various stratigraphic horizons (also for recent deposits). It is also necessary, in order to proceed to the next step in the investigation of bedding, to establish a genetic classification of bedded and unbedded structures.

The genetic classification will have to be built up principally from complex types and combinations of simple morphological types. Its basis will not require morphology of the bedding sets but in stead, the complex of sequential sets; unification of various different morphological types. The solution of this interesting and important problem, i. e. production of a unified genetic classification of structures, is the concern of the immediate future.

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* Originals in Russian

ON THE RELATIONSHIP BETWEEN CONTINENTAL-ICE MOVEMENT OF ANTARCTICA AND ITS REGIONAL STRUCTURE[1]

by

O. S. Vyalov

• *translated by Research International Associates* •

ABSTRACT

L. Gould's widely accepted scheme for the movement of continental ice in Antarctica, away from a single center, is examined. A new scheme of continental-ice movement is presented, for which there are three major ice-sheds: the Western ice-shed, which extends across Graham Land and the Sentinel Mountains toward Edward VII Peninsula; the Central, or Gould ice-shed, which extends roughly parallel to the Antarctic "horst"; and the Eastern, or major ice-shed, situated within the ice plateau of eastern Antarctica. The basic morphologic elements of Antarctica are distinguished. The origin of the valleys which cut the great Antarctic horst is discussed briefly.

Almost all of Antarctica is covered by a thick mantle of glacier ice, which creeps slowly toward the sea. A scheme, proposed in 1940 by L. Gould [8], for the movement of this ice mass seems to be universally accepted and is frequently cited. The scheme was repeated, with only minor changes, by N. Odell [11] in the latest review of data on the Antarctic. Land and the Queen Maud Range, where individual mountain peaks rise over 4,000 meters (m) above sea level (Fridtjof Nansen Mountain, 4,010 m; Kirkpatrick Mountain, 4,450 m; and Markham Mountain, 4,572 m). The ice-shed extends roughly along the 150° meridian and veers to parallel the Ross Sea shore, passing between the Queen Maud Range and the South Pole.

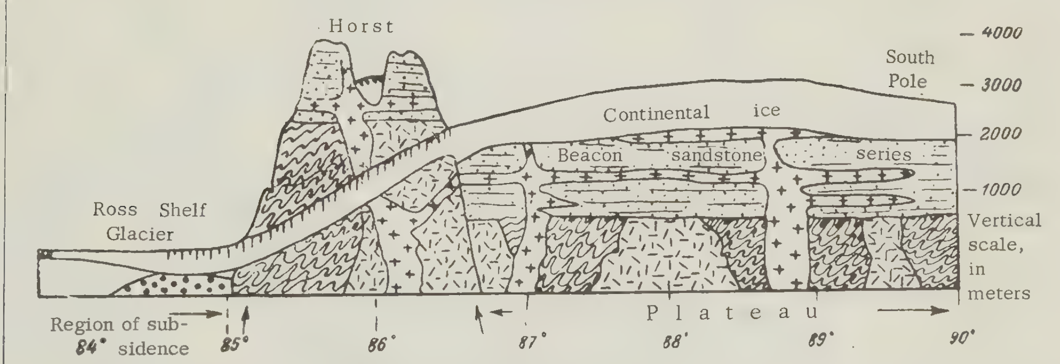

FIGURE 1. Cross-section across the Queen Maud Range and the polar plateau, after L. Gould

The essence of Gould's scheme is that the ice mantle is sharply asymmetrical, and that ice movement is from a single ice-shed situated near the Ross Sea coast. This ice-shed extends somewhat west of the great Antarctic horst (an extensive mountain region bordering Ross Sea on the west and south). The region includes parts of the mountain range of southern Victoria

The ice spreads from this ice-shed in all directions toward the continental margin. From the ice-shed, the mass moves toward the Ross Sea as thick drainage glaciers which cut directly through the mountain barrier (fig. 1). On the opposite side of the ice-shed, the ice moves gradually over the vast area of the Antarctic plateau toward the Atlantic and Indian oceans. From the northeastern slope of the ice-shed, the ice moves toward the Otis Coast; from the western slope, it moves toward the Pacific Ocean (fig. 2).

The general picture of ice movement is completely different. An alternate scheme, depicted in Figure 3, is based on the assumption that

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[1] Translated from O svyazi napravleniya dvizheniya materikovogo lda Antarktidy s yeye geologicheskim stroyeniyem: Moskovskogo Obshchestva Ispytateley Prirody, Byulleten, Otdel Geologii, v. 34, no. 1, p. 109-116, 1959.

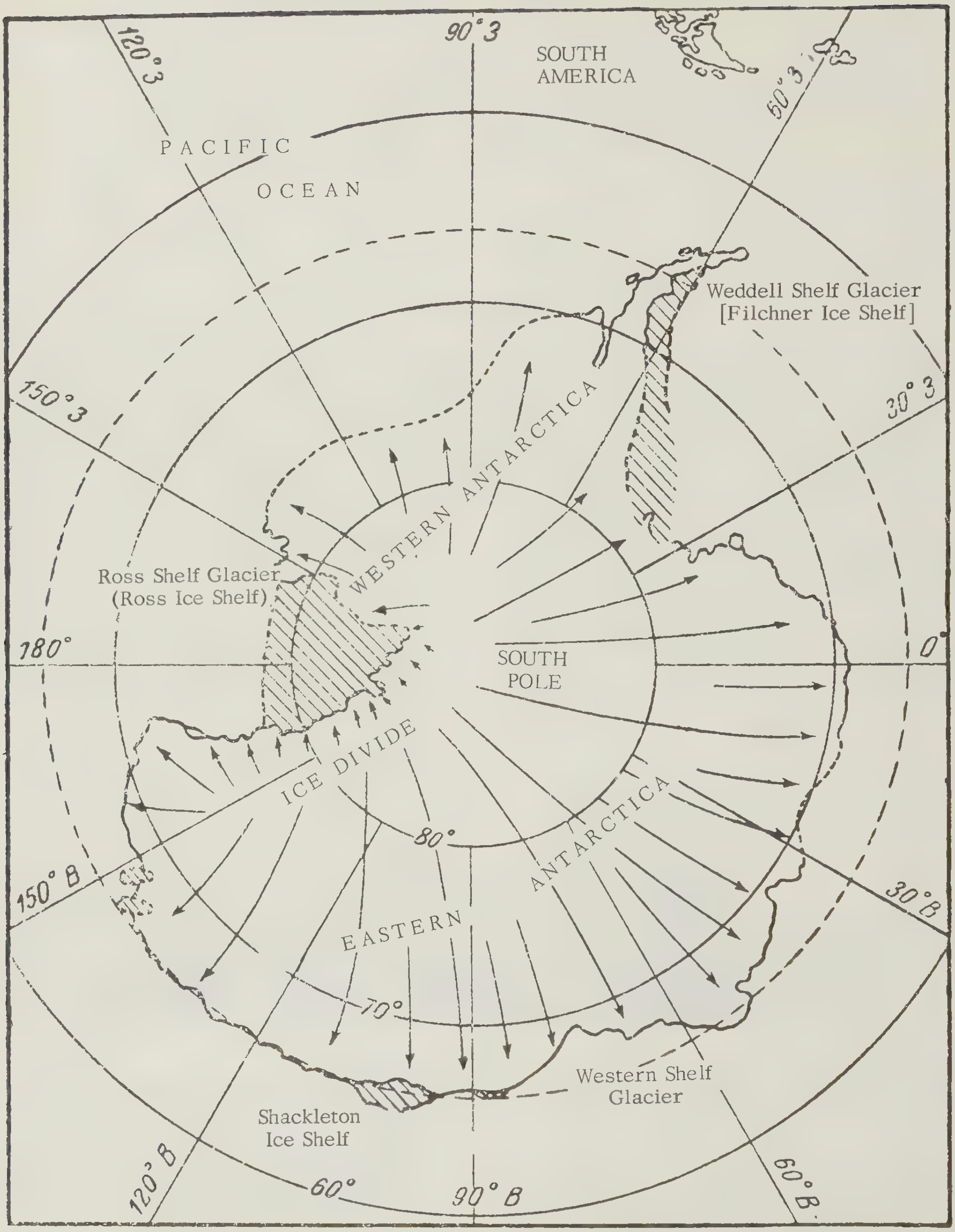

FIGURE 2. Scheme for the movement of ice in the Antarctic, after L. Gould [8] with changes by H. Odell [11]

western and eastern Antarctica are divided by a wide low belt extending from Ross Sea to Weddell Sea.

Elevations measured by L. Ellsworth during the 1935 expedition [5], as well as other data, already depicted on existing maps [1, 2, 10], indicate that the central parts of western Antarctica are considerably elevated relative to the Ross-Weddell depression. It is difficult to imagine how the ice could descend from the ice-shed, cross the depression, and mount the

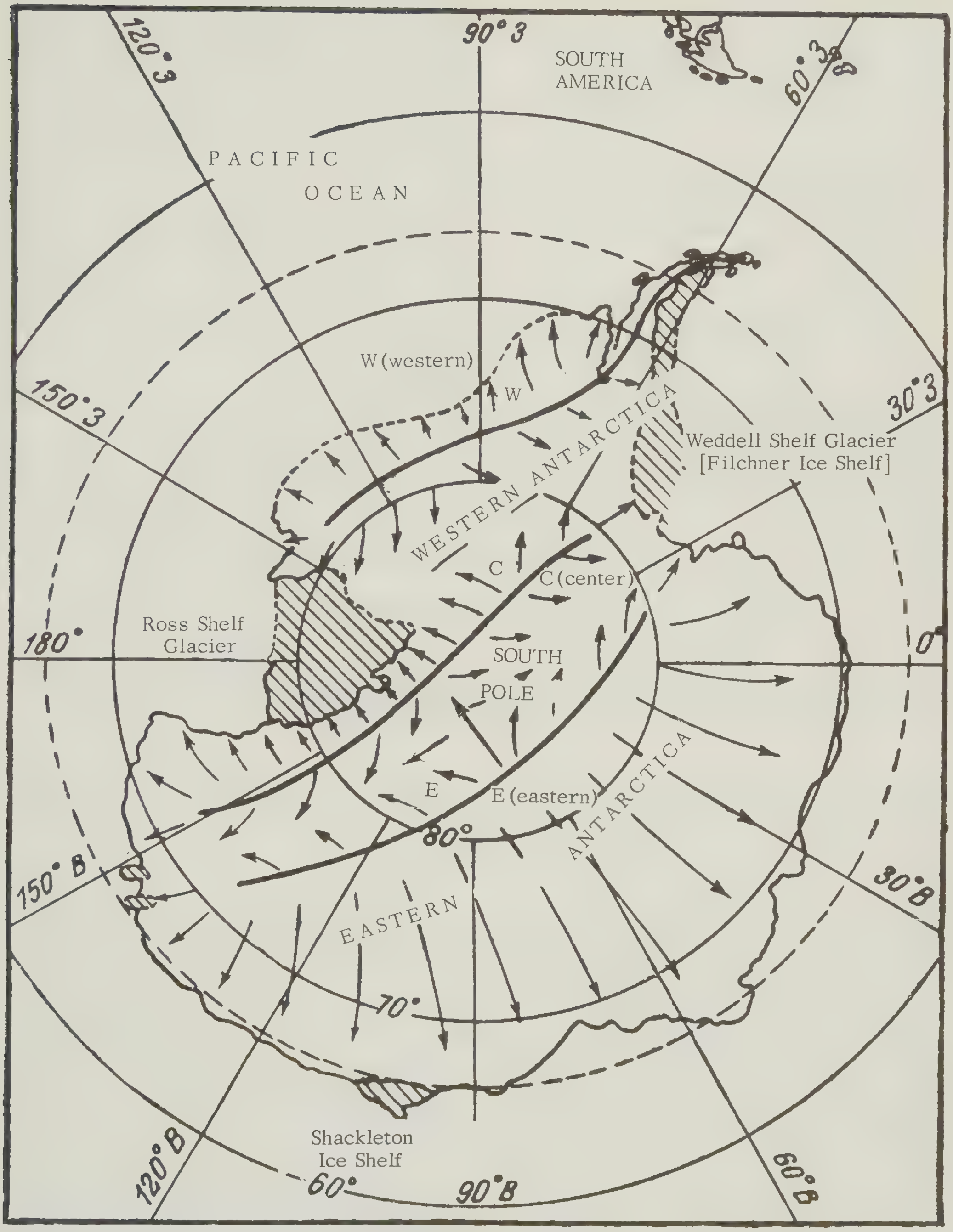

FIGURE 3. Proposed main ice centers and scheme of ice movement in the Antarctic.

Ice centers: W-Western; C-Central; E-Eastern (Major)

elevated part. Since western Antarctica extends to the Pacific Ocean, it would seem more natural to postulate a separate ice-shed in western Antarctica. Just exactly where this ice-shed would be is difficult to say. Quite possibly, it originates in the axial part of Graham Land and extends along Sentinel Range, Hollick Kenyon plateau, and on to the Edward VII Peninsula. On the map, the location of this ice-shed is quite tentative. From this western ice-shed, the ice moves, from one side, toward the Pacific Ocean and, from the other, to the

Ross-Weddell depression.

The second ice-shed is situated more or less as shown in Gould's scheme; however, it does not cross the Ross-Weddell depression, but extends along it. This can be called the Central, or Gould ice-shed.

T. David and R. Priestley [4] have construct- a profile from Ross Sea to the region of the magnetic pole (fig. 4). From Ross Sea, the skaya, 375 km from Mirny, is situated on the plateau at an elevation of 2, 700 m. These data and some elevation determinations facilitated the construction of a profile along the Mirny-South Pole line, which extends through western Antarctica (fig. 5 A). This, of course, is only a preliminary scheme lacking in details, but it does present the general relief of the ice surface.

A relatively steep uplift [of the ice surface?]

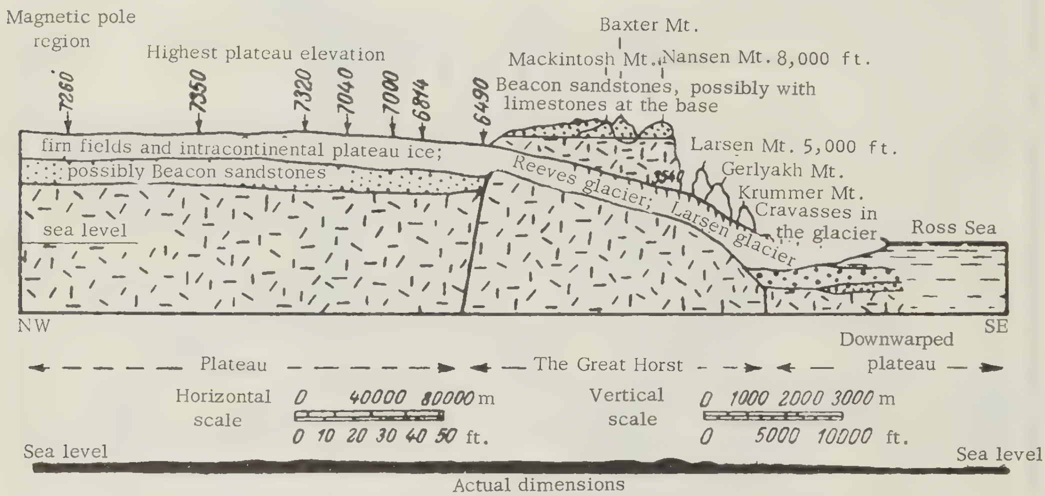

FIGURE 4. Cross-section across Victoria Land from the region of the magnetic pole to the Ross Sea, after T. David and R. Priestly [4]

surface of the glacier, penetrating the coastal range of southern Victoria Land, rises steeply toward the southern margin of the mountains. Here, at an elevation of 1, 978 m, is the margin of the polar plateau, which rises gradually, over a distance of 160 kilometers (km), to 2, 240 m. Past this point, it drops just as gradually to the magnetic pole region where, 70 km from the crest, the elevation is 2, 213 m. Thus, this profile permits one to observe the extension of the Central ice-shed in this part of the continent at a relatively short distance from its margin. Apparently, this is a more gradual region [?] near the terminal end of the ice-shed.

Still one more ice-shed has been positively identified, mainly as a result of data obtained from the 1956 Antarctic Expedition of the Academy of Sciences of the U. S. S. R. Nonstop flights, conducted by M. M. Somov in the region of the Vostok station and in the direction of the "inaccessible" pole, and elevations determined by D. N. Morozov, the pilot, showed that the elevations of the ice surface in this part of the plateau are over 3, 500 m. Pioner- occurs approximately 100 km from the seashore; farther on, the Antarctic plateau rises gradually toward the south. At 200 km from the shore, its elevation is 2, 000 m; at 375 km (Pionerskaya), 2, 700 m; and, from recently obtained data, at 635 km (Vostok I station), approximately 3, 300 m. In the region of the Vostok station, approximately 1, 400 km from the shore, it is approximately 3, 500 m in elevation. Finally, the altitude of Sovietskaya is approximately 370 [3, 700?] m.

The elevation of the South Pole is 2, 765 m [2]. In other words, in the interval Vostok-Sovietskaya, there still may be some increase in the elevation of the plateau; beyond it, the plateau should begin to slope downwards. Thus, the crest of the plateau surface should be situated somewhere between the South Pole and the Vostok-Sovietskaya line. This crest belongs to the third and largest ice-shed. Which direction the crest on the ice-shed takes is difficult to say. It has been tentatively established parallel to the second (Central) ice-shed, extending toward Coats Land in one direction

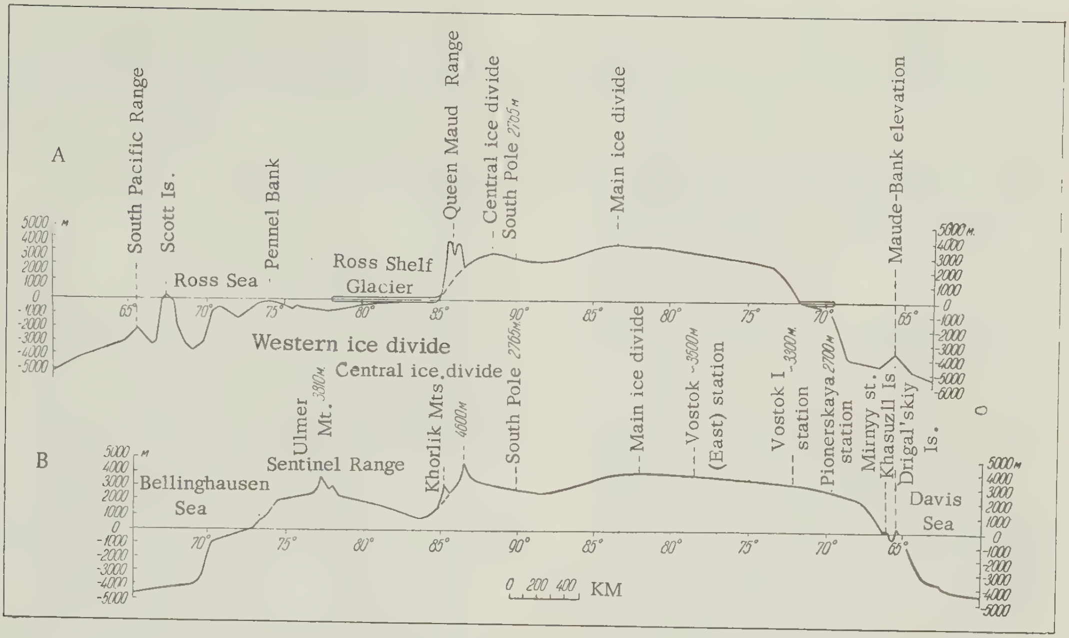

FIGURE 5. Schematic profiles.

A. Along the meridian 87° west longitude--93° east longitude, across Ulmer Mountains--South Pole--Mirny station. (The elevations of stations Vostok, Komsomol and Pionerskaya are given along the line of the profile).

B. Along the meridian 0--180° through Scott Is.--South Pole--Queen Maud Land.

and toward King George V Coast in the other. The main ice masses of Antarctica move from the Eastern (Major) ice-shed north to the continental margins.

It should be noted that on several maps, the 4,000-m contour and the elevation points 4,200 and 4,300 are drawn along the ice plateau of Queen Maud Land, directly south of the mountain belt. This applies to the map of Antarctica compiled by G. Kozak [10], as well as to our maps in the Morsky Atlas, [1], and in the Atlas Mira, in map GUGK, on a scale of 1:20,000,000 published in 1956 [2]. This occurred, apparently, as a consequence of the German 1938-1939 expedition to New Schwabenland [12]. However, as has been explained by the Norwegian-Swedish-British expedition of 1949-1952 on the Norsel, the elevations of the German maps were all too high, locally by as much as 1,000 m [13]. On the map resulting from this expedition, the margin of the Naymeyr ice plateau is at approximately the 2,400-m contour; the latest maximum elevation determined approximately at latitude 74° was 2,700 m [9]. As this is only the margin of the plateau, it may be expected to be higher. It is quite possible that here, past the 80° parallel, will be the highest part of the plateau; on the other side of the ice-shed, it will again slope downwards. This has been shown on our profile (fig. 5 B).

Between the Eastern and Central ice-sheds, there apparently exists a depressed belt along which ice from both ice-sheds descends in the direction of the George V coast and in the direction of Coats Land. (This depressed belt has been found recently by P. Siple.) Thus, in this belt, still another transverse ice shed, tentatively indicated in the scheme, should occur. The maximum elevation of this ice-shed quite possibly reaches 4,500 m. In the region of the transverse ice-shed connecting the Major (Eastern) and Central ones, the elevations of the latter reaches 3,344 m [2]. Thus, here the Major ice-shed is considerably higher and it is quite possible that ice moves directly over the connecting ridge toward the Central ice-shed and then farther to the west. It is also quite possible that such an ice belt, not being diverted into the depressed region between the two ice-sheds, but moving directly to Ross Sea, has considerable width. A second connecting ice-shed, supposedly, should be situated in the Ross-Weddell depression. It separates ice masses which descend from the Western and Central ice-sheds and moves along the depression toward either the Weddell on the Ross seas.

Three basic ice-sheds exist in Antarctica: the Western, Central (Gould), and Eastern (Major), and not one, as universally accepted. Two depressions exist between them, which are

in turn bisected by transverse ridges. The main morphologic elements of Antarctica can be distinguished in relation to the above-mentioned structures: the eastern Antarctic plateau, the Eastern center, the intracontinental depression, the Central center, the mountain barrier or Queen Maud-southern Victoria mountain chain (Ross Sea coast), the Ross-Weddell depression, the Graham Peninsula mountain belt, the western Antarctic plateau containing part of the Western ice-shed along which ranges of bedrock crop out. Besides these there are the large sections of thick and deeply dissected bedrock which occur predominantly at the margins of the continent. This applies particularly to the mountainous region of Queen Maud Land.

The controversial question of the age and genesis of the deep transverse valleys which cut across the mountain barrier of the Ross Sea coast and through which glaciers descend from the Central ice-shed to the Ross ice shelf, is very interesting. David [3, p. 21] speaks cautiously of a possible tectonic origin for these transverse valleys in the mountains of southern Victoria. Gould emphatically supports this with respect to the mountain system of southern Victoria and Queen Maud Land. Moreover, as supporting evidence, he points out that they are faulted, linear, and steep-sided [7, p. 978].

The age of the great Antarctic horst is debatable. K. Rayt [14, p. 2] noted the interesting fact that the ice-shed, the highest point on the ice sheet on the polar plateau, closely adjoins the horst or coastal range. He proposed that the asymmetrical position of the ice range is the result of contemporary and, probably, continued uplift of the horst which involved parts of the continent under the ice cover. However, according to Gould, the basic uplift of Queen Maud Range could not be contemporary, this view is supported by the prolonged erosion which took place after uplift.

According to Gould [7, p. 979], all investigators of the tectonics of Antarctica come to a common conclusion that the main movements which caused the formation of this normal block-fault system occurred in the late Mesozoic or early Tertiary. Moreover, considerable movements could have occurred later, as indicated by the volcanic activity there today. Fairbridge [6, p. 68] suggests that the great Antarctic horst was uplifted subsequent to the deposition of the Paleozoic Beacon sandstone series. However, its rise undoubtedly was considerably accelerated in Tertiary time, during the main faulting period. Obviously, the uplifts could have originated during the Pleistocene as a result of the ice sheet which, in the period of maximum glaciation, was "several thousand feet thick." Still and all, writes Fairbridge, the epigenetic nature of the main glaciers cutting across the great horst indicates considerable erosion during uplift, probably during the Tertiary when there was little or no ice. As for the explanation of uplift due to unloading, it has always seemed rather odd that the phenomenon of unloading or loading of ice is invoked as a factor in downwarping, as well as in oscillatory movements. Why is it that oscillatory movements are attributed to general tectonic causes under ordinary conditions but that these causes are disregarded or minimized when they are applied to areas covered by ice? Do they cease to exist, or are they so slight that they are obliterated by the ice load or its unloading? According to the profile across Ross Sea, the great Antarctic horst, and the internal polar plateau (figs. 1 and 5), the horst is uplifted considerably above the polar plateau, supposedly because it is lighter and does not have a thick cover of ice which cause the internal part of the continent, the polar plateau, to subside. This means that the massif, composed of basement rock and lifted above the polar plateau, has a lighter load than the polar plateau, which is composed of basement rock in its lower part and ice in its upper; therefore, basement rock weighs less than ice. If loading was involved, then the heavier, thicker horst should be subsiding. Why has the Ross depression subsided, and not lifted, once it was freed from the ice sheet? Also, most investigators have abandoned the concept that subsidence, as in foredeeps adjacent to folded-mountain regions, is due to the load of clastic sediments deposited within the depression. On the contrary, molasse sediments fill a subsiding depression, but the subsidence is due to internal tectonic causes.

Ice loading or unloading does not have any effect on oscillatory movements; subsidence or uplift is due to internal, not external, forces. In particular, it is not possible to relate the continued uplift of the great Antarctic horst to a decrease in the ice sheet.

Each of the transverse valleys which cuts across the great Antarctic horst cannot conceivably represent a transverse graben subsequently filled with ice which have found in them an outlet to the sea. It would seem more likely that the movement of ice in the direction of the Ross Sea occurred before the formation of the horst and the mountain region. As the horst was uplifted, the ice sheet penetrated the coastal range as individual glaciers cutting through separate valleys. Thus, it is proposed that the valleys are actually antecedent and that the horst uplift, together with the formation of the whole mountain region, occurred during the glacial stages; that is, probably in the Quaternary.

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Review Section

THE KUDINOV VIBRO-PISTON CORE SAMPLER: RUSSIAN SOLUTION TO UNDERWATER SAND-CORING PROBLEM.[1] Review by John E. Sanders, Department of Geology, Yale University.

ABSTRACT

The Kudinov vibro-piston core sampler has been developed recently by Russian scientists to take undisturbed underwater core samples of sand, 4 to 6 meters long, from the shallow shelf areas of the Black Sea. The device is activated by an electromagnetic vibrator of the type used to settle concrete and features a one-way permeable piston inside the sampling tube which allows upward but not downward flow of water. The weight of the sampling tube and vibrator plus the up-and-down vibration of the sampling tube cause penetration into the sand. Water from the sediment passes upward through canals in the piston, which itself rises in the sampling tube as the sample enters.

The device differs from the Kullenburg-type of gravity free-fall piston corers in that the piston is not connected to the winch cable, but to a counterweight apparatus inside one of the two vertical supporting tubes. An additional feature is the arrangement which permits the sampling tube to be pivoted to a horizontal position on board ship when the sample is removed.

The maximum water depth in which the Kudinov core sampler operates is 150 meters. An electric cable from the shipboard power supply is required in addition to the winch cable.

DESCRIPTION OF THE KUDINOV VIBRO-PISTON CORE SAMPLER

The Kudinov vibro-piston core sampler is recently invented Russian device for taking cores of sand underwater. It operates on the principle of a gentle up-and-down vibration of the sampling tube, which breaks up the cone of pressure that forms around the lower end of a tube that is given only a steady pressure impulse or driven by widely separated blows. In addition the sampling tube is fitted with a piston which operates like a water lift-pump, in that this piston permits passage of water upward from the sample, but not in the opposite direction. The entire sampler consists of a platform at the base, two vertical supporting tubes, a traveling vibrator support mounted at the top of the sampling tube, the one-way permeable piston inside the sampling tube, and the vibrator, vibrator housing, and accessory attachments.

Figures 1 and 2, copied from Kudinov's paper of 1957, show both a general view of the device in various positions, and the details of the model known as vibro-piston core sampler of the Institute of Oceanology of the Academy of Sciences of the U. S. S. R., model WPGT-56.

The steel tubing used has a diameter of 53.5 mm. (inside or outside measurement not specified), and a wall thickness of 5 mm.

The one-piece traveling vibrator support (1, of fig. 2) consists of two sleeves mounted on the outside of the supporting tubes and a vertical steel plate; these parts have been welded together. A circular hole is cut out of the upper part of the plate to accommodate the vibrator housing (3, of fig. 2), which is fixed to this plate by bolts with its long axis at right angles to the plane of the plate. Two pulleys are fastened to the plate below the vibrator housing to permit passage of a cable from the piston within the sampling tube to the counterweight inside the shorter supporting tube. A small brake lever is fixed next to the center pulley. This brake arrests the piston cable during extraction of the sampling tube and prevents the piston from falling downward and possibly forcing out the sample. One end of the brake lever is connected by a brake cable to a slightly longer, but similarly oriented, lever at the top of the vertical plate of the traveling vibrator support. The attachment ring for the cable to the shipboard winch which raises and lowers the instrument is also made fast to the upper part of the plate of the traveling vibrator support; it activates the upper lever. When tension is exerted on the winch cable the upper lever arm is raised; the brake cable transmits the motion to the brake lever, which, when lifted, arrests the piston cable. The lower part of the vertical plate of the traveling vibrator support is cut out to allow seating of the top of the sampling tube. A rotatable collar

[1] Based on an article by E.I. Kudinov, Vibropiston core sampler: Trudy, Oceanological Institute, Academy of Sciences of the U.S.S.R., vol. 25, p. 143-152, 1957, as translated by Marian Ksiazkiewicz, Jagellonian University, Cracow, Poland.

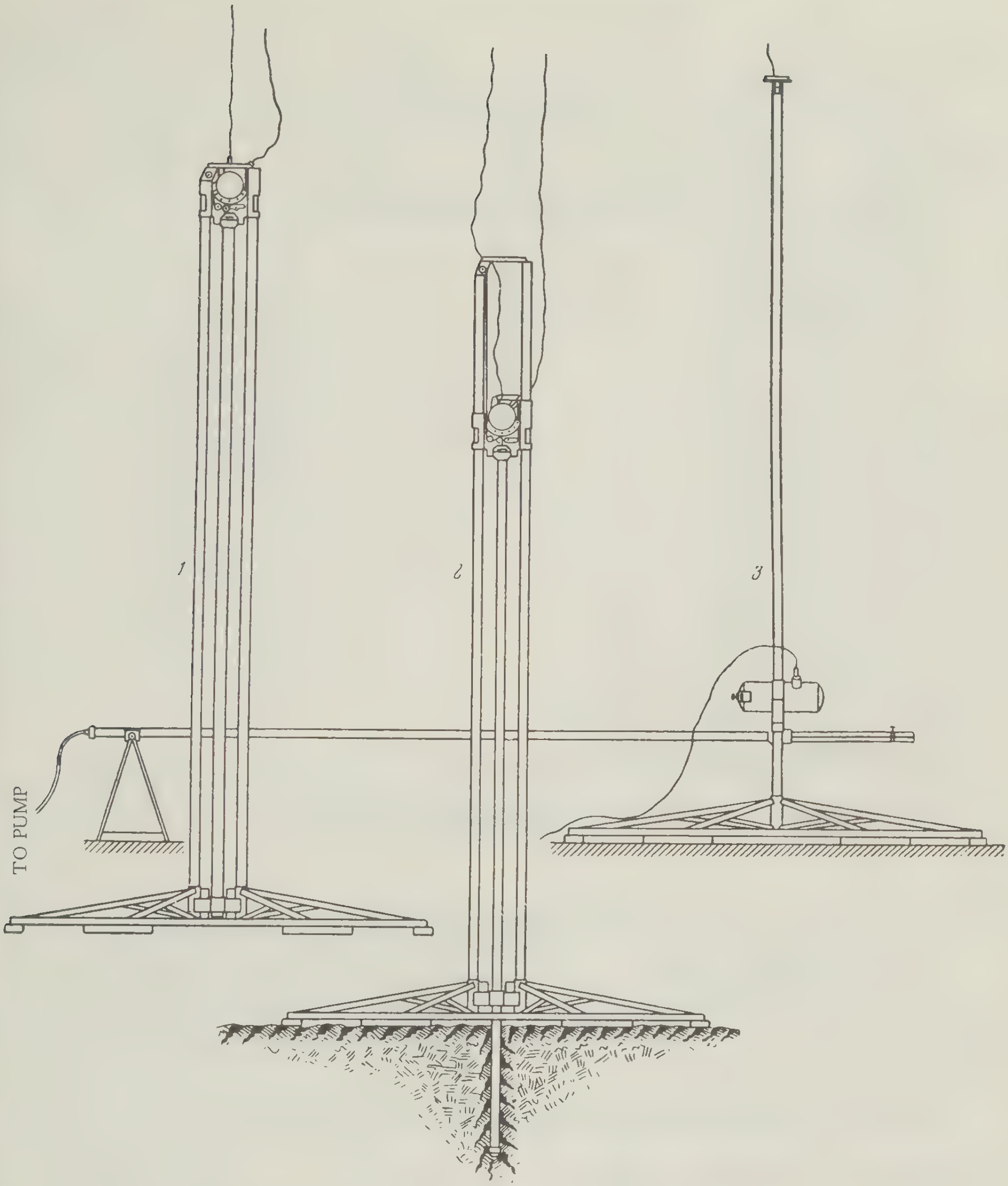

FIGURE 1. General views of the Kudinov vibro-piston core sampler

1) Sampler suspended on the winch cable, nearing bottom preparatory to taking sample. Winch cable (left) and electrical cable to vibrator (right) are shown at top of sampler. 2) Instrument resting on bottom, with sampling tube penetrating part way into the sediment. Winch cable (left) slack; electrical cable to vibrator (right) at top of sampler. 3) Instrument on deck of ship after sampling. Sampling tube is in horizontal position for ease of removing sample. (View 3 is at right angles to views 1 and 2). Winch cable at top (extension down to traveling vibrator support not shown behind supporting tube); electrical cable to vibrator at bottom; piston cable slack at extreme left of figure (top of sampling tube). Accessory support for sampling tube is also shown at extreme left.

with horizontal axis of rotation is mounted in the cut-out area; this collar receives the upper end of the sampling tube with a sliding connection. This arrangement permits the sampling tube, when loosened at its lower end, to be swung from the vertical to a horizontal position and to be slid back and forth horizontally without disassembly, thus facilitating removal of the sample on board ship even though the rest of the instrument is in the vertical sampling

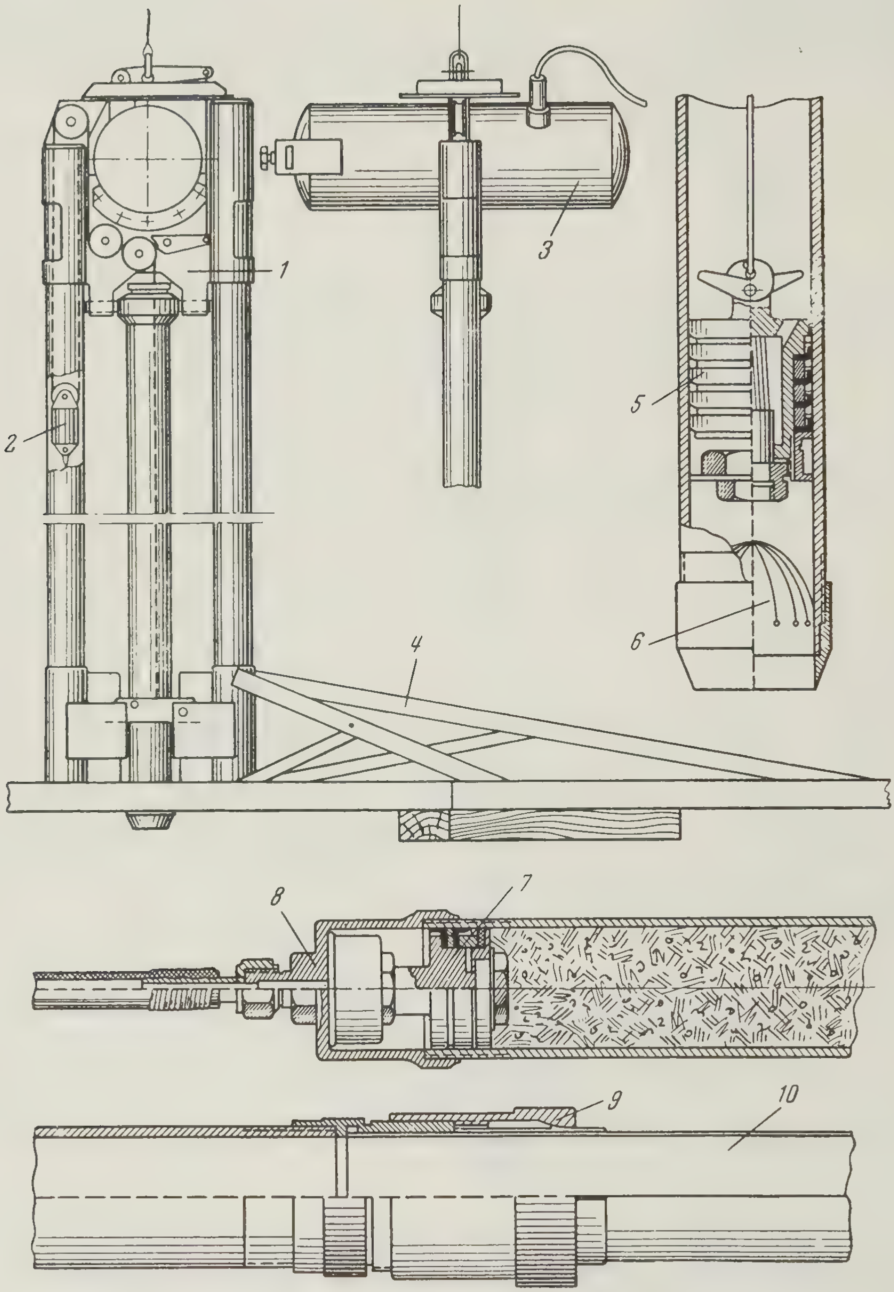

FIGURE 2. Details of the model WPGT-56

1) Traveling vibrator support atop sampling tube (in position prior to taking sample). 2) Counterweight assembly inside shorter supporting tube (shown at uppermost operating position with limiting cord, below, taut). 3) Vibrator housing. Removable cap (left) in closed position. 4) Platform. 5) One-way permeable piston inside sampling tube (shown at lower end prior to taking sample). 6) Ragbolt core catcher. 7) Piston puller (Piston shown at top of sampling tube after taking sample). 8) Piston stopper. 9) Tongs. 10) Grooves.

position (3, of fig. 1).

The two supporting tubes are joined at the top by a ring which allows passage of the cable from the winch (top of 2, of fig. 1). The supporting tubes are attached to the platform at their lower ends; they keep the sampling tube vertical and guide the movement of the traveling

vibrator support. One of the supporting tubes is slightly shorter than the other in order to permit a pulley connection for the piston cable from the vibrator support into the top of the shorter tube to the counterweight apparatus which is contained within this shorter supporting tube (2, of fig. 2). The free end of the piston cable is threaded through the counterweight pulley and fixed to a clamp at the top of the shorter supporting tube.

The counterweight is designed to take up the slack in the piston cable that forms when the piston rises inside the sampling tube during sampling; this prevents the piston cable from becoming fouled. The upward movement of the counterweight is limited by an arresting cord that is attached to the platform at its lower end. Before the sampling tube enters the sediment the counterweight is in the middle of the supporting tube, the limiting cord is taut, and the piston is in the lower end of the sampling tube. As the piston rises inside the sampling tube during entry of a sample, the counterweight moves down and takes up the slack in the piston cable. When the instrument is on deck after extraction and lifting, the limiting cord is unfastened from the platform in order to allow the sampling tube to swing into a horizontal position for sample removal.

The platform which supports the apparatus on the sea bottom is made of fused carbon steel. It consists of two parts, connected with bolts; its plan view is octagonal. The two supporting tubes are firmly attached to the platform by means of two vertical sleeves. Two steel plates are welded to each sleeve; these plates form the lower attachment mechanism for the sampling tube. A rotatable C-clamp is attached between the plates and arranged so that it can swing free of the space between the plates in order to allow the sampling tube to be swung from the vertical to the horizontal. Small wooden blocks are mounted at the edges and bottom of the platform to protect the sides and deck of the ship from the steel edges.

The vibrator consists of a standard 2- or 3-kilowatt electrolift of 3-phase current, an electromagnetic device of the type I-15, prepared by the factory of Jaoslaw and called "Red Lighthouse," that is used for settling concrete. It is fitted into a thick-walled steel drum, 43 cm long and 11.4 cm in diameter, the vibrator housing (3, of fig. 2), which is permanently closed at one end, but fitted with a water-tight removable cap at the other end. The cap is closed by means of an external screw that passes through a U-shaped clamp welded to the outside of the vibrator housing; a plastic washer prevents entry of water. A plug joint admits the electrical cable which supplies the power to the vibrator. The construction used will keep water out of the vibrator housing down to a depth of 200 meters.

The vibrator[2] has 4 eccentrics, with two situated on either ends of the rotary wheel. The two eccentrics nearest the rotary wheel rotate in one direction; the other two, situated marginally, rotate in the opposite direction. The opposite rotation is achieved by an indented gear placed on both ends of the rotary wheel between the eccentrics. Rotating in opposite directions, all four eccentrics arrive in their upper and lower vertical positions at the same time and then separate in pairs toward the sides. This gives the sampling tube its vertical vibration. The kinetic moment of each eccentric is 6.5 kg/cm. The weight of the vibrator is approximately 30 kg.

The piston (5, of fig. 2) is the most important component, for it governs the quality of the samples. The piston should be easily raised by a force of 2-3 kg. It must be impermeable to water entering from above downwards, but should allow free passage of water from below upwards. This one-way flow is achieved by means of 4 leather washers with their concave side upward and by a canal and valve arrangement through the piston. The upward-moving water passes through the piston via a cylindrical canal which communicates to the space above the piston after passing a ball valve or float valve. When the pressure is greater from above the valve closes, rendering the piston impermeable. When the pressure from below is greater the valve opens and transmits the water through the cylindrical canal to the upper part of the sampling tube above the piston.

Two latches atop the piston receive the knot of the piston cable. This cable can be released when the core is removed from the sampling tube by using a fissured cylinder.

A special attachment whose aperture is slightly larger than that of the sampling tube is used to introduce the piston into the sampling tube. This attachment is screwed onto the sampling tube, the piston is inserted, and the attachment is afterwards screwed out.

The lower end of the sampling tube is ground to a cutting edge to facilitate penetration into the sediment.

A small accessory support (extreme left side of 3, of fig. 1) receives the sampling tube when the tube has been rotated into a horizontal position aboard ship to remove the sample.

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[2] No drawings of the vibrator accompanied Kudinov's paper which described the core sampler. It is operated by an induction motor on 3-phase alternating current of 75 cycles per second; the electrolift rotates at 5700 r.p.m.

DISCUSSION

Use of the vibro-piston core sampler of the Institute of Oceanology of the Academy of Sciences of the U. S. S. R., model WPGT-56, has resulted in the taking of successful cores of sand 4-6 meters long in water up to 150 meters deep. The device has been employed to date chiefly for study of sediments of shelf areas of the shallower parts of the Black Sea (Nevessky, 1958; 1959; Zenkovich, 1959). The cores have been reported to show little distortion and to preserve delicate sedimentary structures. A small amount of compaction has occurred, but a special investigation of this phase of the operation revealed that it is of minor importance.

Where a coring tube is pushed into sand by steady pressure (by gravity fall, for example) or by isolated blows, it may continue to penetrate into the sand even after no more sample enters the sampling tube. Eventually all penetration ceases when the pressure that builds up in the sediment below ahead of the tube equals the force of entry. This plugging of the open end of the sampling tube by compacted sand and the build-up of a cone of pressure in the sediment below the sampling tube do not occur when repeated up-and-down motion of the sampling tube is used [3]. Thus, the Kudinov device overcomes the difficulty that has limited the effectiveness of free-fall types of coring instruments when the bottom consists of sand. Kudinov's instrument should open the way for important results in the study of continental shelf sediments, which have hitherto been known chiefly from dredge samples.

REFERENCES

1. Kudinov, E. I., 1957, Vibro-piston core sampler: Oceanological Inst. Acad. Sci. U. S. S. R., Trudy, v. 25, p. 143-152.

2. Nevessky, E. N., 1958, Methods of investigation of littoral deposits by means of the vibro-piston core sampler: Oceanological Inst. Acad. Sci. U. S. S. R., Trudy, v. 28, p. 3-13.

3. ———————, 1959, Study of the formation of littoral deposits as a method of analyzing the evolution of the sea floor (abstract): Int. Oceanographic Congress, New York, Preprints, p. 643-644.

4. Zenkovich, V. P., 1959, The sea relief and sea coastal zone structure changes and their effect upon the total ocean complex (abstract): Int. Oceanographic Congress, New York, Preprints, p. 671-672.

[1] L.M.J.U. van Straaten, University of Groningen, The Netherlands (personal communication) has observed that these same pressure-effects occur in sampling sand on Dutch beaches and tidal flats even when a hand-operated coring tube only 1 meter long is used.

THE GEOLOGICAL STRUCTURE OF THE U. S. S. R., IN FRENCH TRANSLATION. Communication by C. F. Davidson, Department of Geology, University of St. Andrews, Scotland.

In International Geology Review for October, 1959, E. A. Alexandrov reviews at some length the three comprehensive volumes on 'The Geological Structure of U. S. S. R.' produced (in Russian) under the general editorship of A. P. Markovsky. Following his excellent conspectus of the contents of this fundamental and important text, Alexandrov concludes that "it would not be practicable to recommend a translation of this voluminous work". Whilst few Western geologists have much knowledge of Russian, most can read French without difficulty; and as an addendum to Alexandrov's commendable review it therefore seems appropriate to note that a French translation of the Russian text is currently being published by the Centre National de la Recherche Scientifique. This translation by M. Pietresson de Saint Aubin and M. Roger (of the Bureau de Recherches Geologiques, Geophysiques et Minieres) is lucidly written and well produced. It will do much to make the main geological features of the U. S. S. R. better known to Western readers.

At the close of 1959, translation of the 'Stratigraphy' volume had been completed, with six fascicules published (as noted below). Work on the volumes dealing with 'Magmatism' and 'Tectonics' is in progress; and these texts are to be accompanied by the new 1:7.5 m. geologic al map and 1:10 m. geomorphological map of Russia. The cost of this subsidized French publication is little more than that of the original Russian work: the six fascicules issued to date, totalling 816 pages, are priced at 33 new francs (about $6.75). The complete bibliography follows: Markovsky, A. P., chief editor. STRUCTURE GEOLOGIQUE DE L'U. R. S. S., VOLUME I, STRATIGRAPHY, edited by N. V. Ovechkin. French translation by Pietresson de Saint Aubin and J. Roger. Fascicules I (Geomorphology), 72 pp. Price 3 N. F.; II (Precambrian), 116 pp., 4.50 N. F.; III (Palaeozoic), 324 pp., 13 N. F.; IV (Mesozoic), 148 pp., 6 N. F.; V (Cenozoic), 88 pp., 3.50 N. F.; VI (Quaternary), 68 pp., 3 N. F. (Paris, 1959, Editions du Centre National de la Recherche Scientifique).

POLISH GEOLOGIC LITERATURE CARRIES RESUMÉS IN ENGLISH. Communication by Alexander Gakner, AGI Advisory Committee

on Translations.

The Polish Geological Institute publishes two continuing but not necessarily periodic series. These are the "Biuletyn" (Bulletin) and the "Prace" (Transactions).

The "Biuletyn" series started in 1938. It was discontinued in 1939 with issue No. 23 and resumed again in 1946. Toward the end of 1959 there were at least 147 issues of the "Biuletyn" published. The "Biuletyns", covering all aspects of Polish geology and ranging in size from 40 pages to as many as 300 pages, usually contain a resumé in one or more often two foreign languages. Since the end of World War II the "Biuletyn" most frequently includes resumés in Russian and English.

The "Prace" series started in 1921. It was discontinued in 1939 with volume no. III, but publication was resumed in 1948 and by 1959 there were at least XXVII volumes. "Prace" is published in quarto size. The post World War II publications usually include a resumé in Russian and English or French.

Kalenov, Ye. N., THE INTERPRETATION OF THE CURVES OF VERTICAL ELECTRIC PROFILING. Communication by Frank C. Whitmore, Jr., AGI Advisory Committe on Translations.

This 472-page text has been translated by G. V. Keller of the Geophysics Branch, U. S. Geological Survey. The translation is presently stored on magnetic tape. Requests for information on its availability, should be directed to James R. Balsley, Chief, Geophysics Branch, U. S. Geological Survey, Washington 25, D. C.

ERRATA

Vol. 1, no. 8, August 1959

p. 74, col. 1, lines 3 and 4 from bottom, formulas should be :

$$a_o + \alpha x_i + \gamma y_i + \delta y_i + 1x_i = \sigma x_i$$
$$b_o + \beta y_i + \gamma x_i - \delta x_i + 1y_i = \sigma y_i$$

Vol. 1, no. 9, September 1959.

p. 39, 40. Wherever they occur, X1/2 should be $X_{1/2}$ and Y1/2 should be $Y_{1/2}$

p. 39. Col. 2, line 7 from bottom:
"ζ = 1.65 km" should be "ξ = 1.65 km"

p. 40, Col. 1, formula 2 should be:

$$\Delta_1 = E \frac{\xi 3}{(x^2 + y_o{}^2 + \zeta 2)^{3/2}}$$

Vol. 2, no. 1, January 1960

p. iii, line 11, and p. 43, heading Mathew N. Nitecki should be Matthew H. Nitecki

p. 8. Abstract, line 10. "-- computed at 24 hours, 17 minutes, 11 seconds; -- should be "-- computed at 45 minutes, 6 seconds; --